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RATION EXPERIMENTS WITH SWINE, 1906--1908

BY

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INTRODUCTION

This bulletin records two experiments, the first conducted during the winter of 1906-07, and the second during the winter of 1907-08. Both experiments were planned to discover what protein feeds would prove most economical when fed with barley and with corn. These two grains are the most available and commonly used of any of the feeds used in this State, with the possible exception of field peas. But neither corn nor barley is an economical feed for hogs when fed alone. This is now recognized in the corn belt, after much experimental work by the various experiment stations. Our problem, therefore, is to find what available feeds may be used in this State to best advantage for supplementing these grains.

THE FEEDS SELECTED.

Alfalfa hay, wheat, field peas, wheat shorts, and packing house tankage were the feeds selected because of their availability throughout the State. Wheat shorts consist of the finer particles of bran and a portion of the kernel within the bran. They contain more starch and less crude fibre than bran, and are less bulky. Selected tankage, a packing house product, is made from residue meat scraps, and has a large percentage of protein.

1906--1907 EXPERIMENTS

Ten lots of ten head each were fed. The pigs averaged from 66 to 70 pounds each when they were put on feed. They were Poland China grades, about six or seven months old, bought in the country surrounding Fort Collins. They were very small for their age but of good enough breeding to show fair returns for feed. They were uniform in breeding, age and condition. At the close of thirteen weeks feeding, the lots ranged from an average weight of 154 pounds per head to 200 pounds per head.

The following table gives the results:

TABLE A.

FEED FOR GAIN AND COST OF GAIN, 1906-07

(Ten head in pen.)

PEN NO.	RATION	Gain per Head 13 Weeks. Lbs.	POUNDS FEED FOR 100 POUNDS GAIN				*Cost of Feed for 100 lbs. of Gain	Standing of Lots
			Grain	Hay	Tankage	Beets		
I.	Barley; alfalfa hay at pleasure	107	508	75	...	...	$5.27	5 and 6
II.	Corn; alfalfa hay at pleasure	115	508	76	...	...	$5.27	
III.	Barley and corn, equal parts; alfalfa hay at pleasure	131	435	67	...	...	$4.52	1
IV.	Barley one part; wheat one part	115	476	..	...	...	$5.95	7
V.	Barley one part; peas one part	111	482	..	...	...	$7.23	10
VI.	Barley one part; shorts one part	117	457	..	...	...	$4.57	2
VII.	Barley ten parts; tankage one part	130	405	..	46	...	$4.97	4
VIII.	Corn ten parts; tankage one part	142	386	..	42	...	$4.70	3
IX.	Barley; beets at pleasure	94	475	..	...	478	$5.95	8
X.	Corn; beets at pleasure	86	544	..	...	498	$6.69	9

* Note—Prices of feeds figured as follows:
Grain, one cent per pound, except wheat 1½ cent and peas 2 cents.
Tankage, at $40.00 per ton.
Beets, at $5.00 per ton.
Alfalfa, at $5.00 per ton.

POUNDS FEED FOR ONE HUNDRED POUNDS GAIN.

The number of pounds of feed required to produce one hundred pounds of gain in live weight is the point of chief interest to the feeder, and it is probably the best comparative method of stating our results from the experiment. So we depend upon this column chiefly for our conclusions.

SUGAR BEETS WITH GRAIN.

Lots IX and X were fed sugar beets with barley and with corn respectively. It will be noticed that each of these lots consumed about as much grain for each one hundred pounds of gain as did the lots fed grain alone, and in addition they consumed about as much beets as grain, making the ration very expensive. Practically no returns were secured from the beets. It is true that these lots ate about one-fifth less grain during the entire period of feeding than the lots not fed beets; but they also gained very much less in live weight as the foregoing Table "A" shows. They gained only 94 and 86 pounds per head in thirteen weeks, whereas the other lots gained 107 to 142 pounds per head in the same length of time.

And it must be remembered that the beets were not forced

upon the pigs by withholding the grain. The beets were supplied as the pigs desired them. Evidently they relished the succulent feed. and ate enough of it so that they had not the capacity for a quantity of grain sufficient to produce a large gain in live weight.

These results with beets were so marked that it was not thought necessary to duplicate this portion of the experiment another season. And we believe that the conclusion is warranted that for light weight fattening pigs, weighing from 60 to 160 pounds, sugar beets are not an economical fattening feed in connection with grain, when they constitute about half the ration by weight—in this instance all the beets which the pigs would voluntarily eat.

ALFALFA HAY WITH GRAIN.

Lots I, II and III were fed alfalfa hay and grain. Of these, lot III, fed equal parts of barley and corn, did the best, making the heaviest gains, and requiring the least amount of feed for one hundred pounds gain. This lot, in fact, made the best showing of any in the experiment, and figuring the price of the various feeds upon any reasonable basis, the cost of producing pork with this ration of corn, barley, and alfalfa hay, was less than with any other ration used in the experiment.

Lot I, fed barley and alfalfa hay; and lot II, fed corn and alfalfa hay, came out almost equally well, although lot II showed slightly greater gains than lot I. Neither barley and alfalfa hay nor corn and alfalfa hay gave such good results as corn, barley and alfalfa hay, being surpassed in amount of gain produced and in economy of ration, by several rations in the experiment.

COST OF FEED AND STANDING OF LOTS.

In the foregoing Table "A" a column is given showing the cost of the rations with the feeds figured at given prices. One cent per pound will approximate the market prices of barley, corn, and shorts, and is a convenient round number from which an advance or lowering of prices may easily be computed. Peas and wheat are ordinarily higher in price and therefore are figured at two cents and one and a half cents respectively. In looking down the column showing the standing of lots, a series of numbers are found showing the relative order of the rations according to their economy. This column is given only for the purpose of facilitating the finding of the most economical rations.

BARLEY AND WHEAT SHORTS.

It will be seen that after the barley, corn and alfalfa ration, the barley and shorts ration, half and half, was the most economical. There was so little difference, however, in the economy of these two rations that one cannot say either proved better than the other. The

barley, corn and alfalfa lot required 435 pounds of grain and 67 pounds of hay for 100 pounds gain; while the barley and shorts lot required 457 pounds of grain for 100 pounds gain. Both rations were very satisfactory.

GRAIN AND TANKAGE.

Lots VII and VIII were fed barley and tankage, and corn and tankage respectively, ten pounds of grain being fed for each pound of tankage. The corn and tankage produced slightly better results than barley and tankage, and both rations were good, coming next to lots III and VI in point of economy.

BARLEY AND WHEAT, EQUAL PARTS.

This ration gave good gains, and required only 476 pounds of feed for 100 pounds gain in live weight. But with wheat at any ordinary figure, the cost of the ration is high. If cheap wheat can be gotten—that is, wheat at the price of corn or barley, the wheat and barley ration will prove a satisfactory one. Barley offsets the tendency towards production of soft and flabby flesh which wheat favors, and the two together give good gains.

BARLEY AND PEAS, EQUAL PARTS.

This ration is not equal in production of gain to any of the other rations except the beet rations, and one alfalfa hay ration. Also, the amount of feed required for gain was 482 pounds—considerably greater than that required by the other rations in which grain or grain by products only were fed. And since peas are ordinarily higher in price than corn or the small grains, the ration does not prove economical.

This, of course, does not mean that a ration of barley fed to swine hogging off peas in the field might not prove economical. These results apply only to threshed peas when fed with barley to hogs that are confined to feed yards.

The following Table "B" gives the digestible nutrients required for one hundred pounds of gain in live weight. The nutritive ratio shows the proportion of protein to carbo-hydrates and fat in each ration; for example with Lot I, the nutritive ratio is 7.8; that is, there was one pound of protein to every 7.8 pounds of carbohydrates and fat in the ration.

TABLE B. (See Table F, in Appendix)

DIGESTIBLE NUTRIENTS REQUIRED FOR 100 LBS. GAIN, ALL PENS

PEN NO.	TOTAL GAIN (Lbs.)	POUNDS OF DIGESTIBLE NUTRIENTS REQUIRED FOR 100 LBS. GAIN			NUTRITIVE RATIO
		Protein	Carbo-Hydrates	Ether Extract	
I.	1066	49.51	377.49	9.01	7.8
II.	1145	49.25	366.41	22.18	7.9
III.	1303	42.64	319.42	13.42	7.81
IV.	1153	43.19	328.10	8.08	8.05
V.	1112	62.41	252.43	5.86	4.27
VI.	1168	46.40	273.63	12.65	6.55
VII.	1299	52.19	281.60	12.76	5.98
VIII.	1417	41.78	259.84	21.99	6.40
IX.	940	63.09	690.21	8.98	11.28
X.	863	69.29	741.13	24.36	11.54

1907--1908 EXPERIMENT

Six lots with eight head in each lot were fed during this experiment. They were fed during the same season of the year and were the same class of hogs and of about the same weight as those described in the previous experiment. The experiment lasted fifteen weeks—two weeks longer than the previous winter's experiment. The pigs were of uniform breeding, age, and condition.

The most promising rations, as shown by the previous winter's feeding, were tried again and selected tankage was tried with various grains.

TABLE I.

FEED FOR GAIN AND COST OF GAIN

(Eight pigs in each pen)

PEN No.	RATION	AV. GAIN PER HEAD, 15 WEEKS. LBS.	POUNDS OF FEED FOR 100 POUNDS GAIN			*COST OF 100 LBS. GAIN	STANDING OF LOTS
			Grain	Tankage	Hay		
1.	Barley three parts, corn three parts, alfalfa hay at pleasure.	116	496	..	56	$5.10	4
2.	Barley three parts, corn three parts, tankage one part	171	338	56	..	$4.50	1
3.	Barley six parts, tankage one part	158	367	61	..	$4.89	3
4.	Corn six parts, tankage one part	164	353	59	..	$4.71	2
5.	Durum wheat six parts, tankage one part	161	360	60	..	$6.60	6
6.	Durum wheat three parts, corn three parts, tankage one part.	173	334	56	..	$5.30	5

* Note—Prices of feed figured as follows:
Corn and barley at one cent per pound.
Wheat at one and one-half cent per pound.
Tankage at $40.00 per ton, (two cents per ℔.).
Alfalfa at $5.00 per ton.

DURUM WHEAT, CORN, AND SELECTED TANKAGE.

Lots 5 and 6 were fed rations containing these grains. Lot 5, which received six pounds of durum wheat to every pound of tankage, made a very good gain in weight, and required only about an average amount of feed to produce 100 pounds gain, so that if the prices of these feeds were not considered the ration would be pronounced a good one. Both feeds are expensive, however, and consequently the cost of gain is too high.

Lot 6, fed durum wheat, three pounds, corn, three pounds, and tankage, one pound, made the best gains of any lot, gaining an average of eleven and one-half pounds per head each week. These required less feed for gain than any of the other lots. If durum wheat can be obtained at the price of corn, this ration will prove very economical.

BARLEY, CORN, ALFALFA HAY.

This ration proved very satisfactory the previous winter, but did not show quite so great economy in the present experiment. The amount of feed required for gain was somewhat greater than the previous winter, and the gains made were less than those made by the other lots in this experiment. This might be accounted for by a difference in the quality of the hays. At any rate, in this instance, the barley, corn, hay ration proved more costly than barley and tankage; corn and tankage; or barley, corn and tankage; although at a cost of $5.10 for each hundred pounds gain, it is still a very good ration.

BARLEY, CORN AND SELECTED TANKAGE.

This ration, with the feeds in the proportion of 3 : 3 : 1, gave the best results of any tried in this experiment. The gain made was eleven and two-fifths pounds per head each week. The amount of feed required for gain was only 336 pounds of grain and 56 pounds of tankage, and the cost was $4.50 for each hundred pounds gain. This cost was practically the same as that for the corn, barley, and alfalfa lot and for the barley and shorts lot of the previous year.

CORN AND TANKAGE, AND BARLEY AND TANKAGE.

The corn and tankage ration was not quite as economical as the barley, corn, and tankage; but was slightly better than the barley and tankage, the cost of 100 pounds gain for the three lots being $4.71, $4.50 and $4.89. All three of these rations were satisfactory and economical.

It will be seen from the following table that the tankage and the wheat rations all supplied a large proportion of protein, while the alfalfa ration apparently did not. It is probable, however, that the alfalfa rations actually furnished a larger percentage of protein than the tables show, because the pigs eat only the leaves and finer

stems of the hay, while the entire amount of hay is necessarily charged up to them.

TABLE II. (See Table VI in Appendix)

DIGESTIBLE NUTRIENTS REQUIRED FOR 100 LBS. GAIN, ALL PENS

PEN NO.	Total Gain in 15 Weeks lbs.	DIGESTIBLE NUTRIENTS, POUNDS			Nutritive Ratio
		Protein	Carbo-Hydrates	Ether Extracts	
1.	931	45.86	355.86	15.13	8.1
2.	1368	51.32	231.97	17.33	5.33
3.	1260	55.79	255.89	14.05	5.19
4.	1309	53.55	238.50	22.63	5.47
5.	1286	62.75	251.79	13.77	4.54
6.	1383	54.52	229.93	17.14	4.97

CONCLUSIONS.

Sugar Beets.—For light weight fattening pigs, weighing from 60 to 160 pounds, sugar beets are not an economical fattening feed in connection with grain, when they constitute approximately one-half of the ration by weight. Our experience indicates that when such pigs are fed beets at pleasure, they will eat the beets and grain in about equal proportions by weight.

Alfalfa Hay.—Where a good quality of leafy alfalfa hay may be had at reasonable cost, and other protein feeds are difficult to obtain or are high in price, the alfalfa hay may be used to supplement grain feed for fattening pigs. It should not be fed with the grain, but should be put in specially constructed racks where the pigs may go to it at pleasure. Mixed grains, with alfalfa hay will give better results than a single grain with hay as a rule.

Barley and Shorts.—Two home grown feeds that can be secured almost anywhere in the State. They make a first class ration when fed together. The millers of Colorado do not ordinarily separate shorts from bran, but will usually do so upon request, at a price about ten cents per hundred in advance of the price of bran.

Barley and Wheat.—Another home grown combination that gives good results. Where a sufficient yield of durum wheat can be secured on the dry lands of the State, this ration will prove particularly well suited to those regions.

Barley and Peas.—Field peas, threshed, are more expensive than a number of other high protein feeds, so that it is well to confine pea feeding to the hogging off of field peas.

Selected Tankage.—This is a very high protein feed containing over 40% of protein; so that only a small quantity of it is necessary with grain. It proved satisfactory when fed either in the proportion of one-eleventh of the ration, or one-seventh of the

ration. With grain at one cent per pound and tankage at two cents per pound, the grain and tankage ration, with the grain forming five-sixths to nine-tenths of the ration, will cost from about $4.50 to $5.25 for each 100 pounds gain upon fattening pigs under two hundred pounds live weight.

What Selected Tankage Is.—The following description of the manufacture of Digester Tankage by Swift & Co., of Chicago, under date of Oct. 3, 1908, gives a good general idea of the methods used in the manufacture of selected tankage for feeding purposes. Such tankage does not contain any part of the animal carcasses condemned because of disease, and if any disease germs should find their way in with foreign matter they would be destroyed by the cooking process with live steam under pressure.

"Digester Tankage is made from small scraps of meat trimmed from residues left in tanks after edible lard and tallow have been extracted from the carcass trimmings, and residues incident to the production of meats for human food purposes. These materials are taken only from animals which have been U. S. Government inspected and passed. This meat is a finished product and is a safe feed, absolutely free from diseased germs.

"In the process of manufacture, the materials mentioned are placed in large tanks which are then sealed and the mass subjected to live steam, usually under a pressure of 40 pounds. The cooking process is timed for four to six hours, depending upon the character of materials handled. When the cooking is completed the steam is turned off and tanks allowed to settle. When the liquid fat is found in a layer at the top it is removed. The residues consist of a watery solution, and at the bottom of the tanks a mixture of small pieces of meat and bone. The liquid is drained off to be dried separately and the solid meat—"The Tankage"—allowed to drain; it is then dried in large steam-heated rotary ovens in which a high temperature is maintained. The dried tankage is ground and put through a mill and screened to the desired fineness. It is then packed in 100-pound sacks ready for shipment.

"Digester Tankage has a very uniform composition, guaranteed 60% Protein, 6% Phosphates, and 8% Fat."

Armour Packing Company, of Kansas City, make the following statements under date of October and November, 1908:

"Our guarantee to the State of Kansas regarding meat meal is as follows:

> 'Made from regular run of good conditioned cattle and sheep offal from which oils and greases have been extracted. Sold under guarantee to contain a minimum of sixty per cent (60%) Protein, but will run as high as sixty-five per cent (65%) in certain lots.'

"This means too only the best of the offal, for what is commonly known as "peck" never goes into such tanks, being kept apart, and the residue of "peck" tanks goes to fertilizer only.

"Recent analyses of our Meat Meal show that in addition to 60% proteids, it contains about 13% fat, and 14.5% ash.

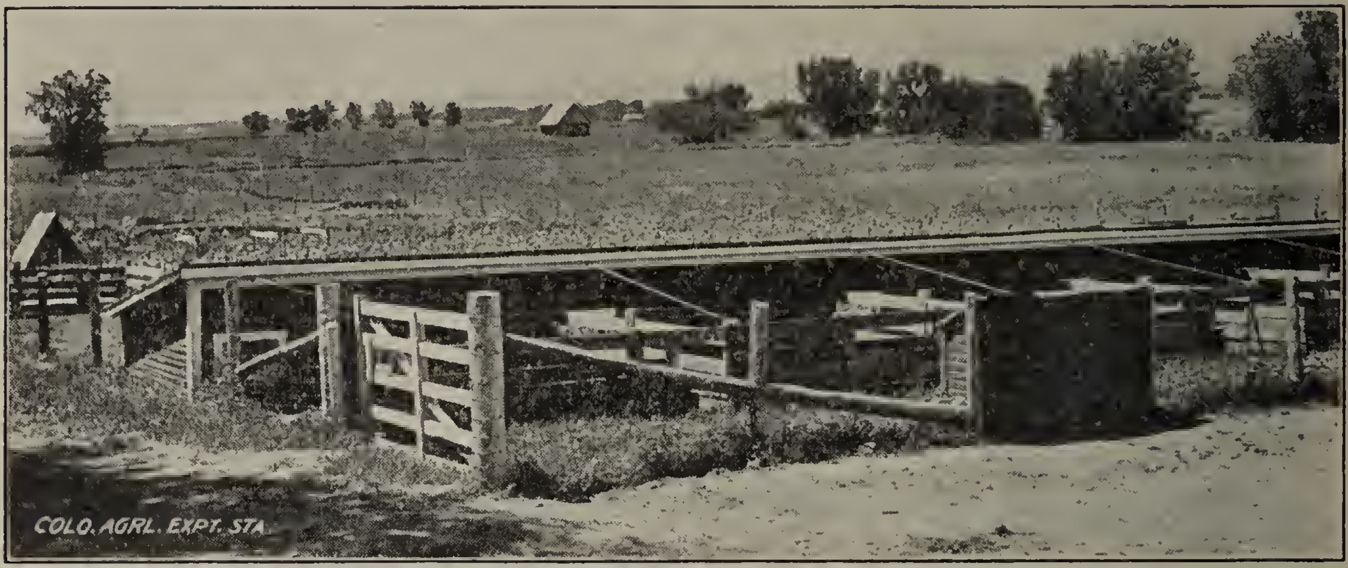
"There is not properly any crude fibre in this, and what foreign matter may get in will not exceed half of one per cent."

The Colorado Packing and Provision Company of Denver, who furnished the selected tankage used in these experiments, have the following to say concerning their product, under date of Oct. 19, 1908:

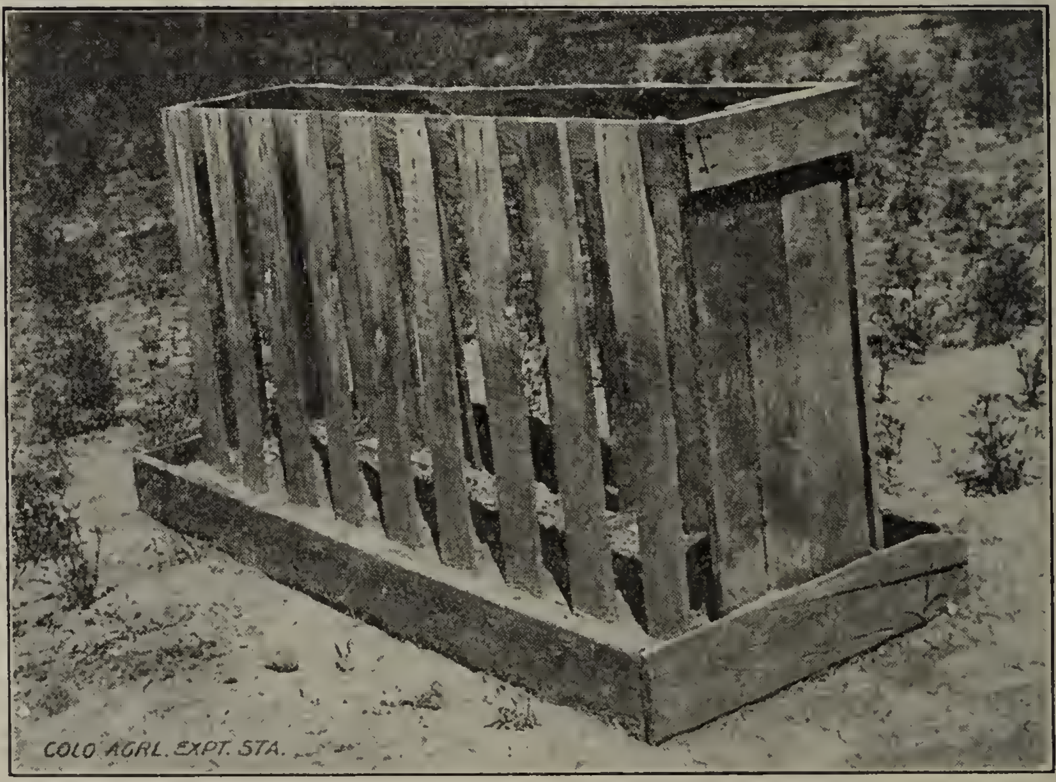
"We will state as near as possible the analysis of our Selected Beef Tankage for stock food:

Water	10%
Protein	55%
Crude Fibre	5%
Free Extract of Nitrogen	7%
Fat	8%
Phosphate of Lime	15%

"This will vary some, as our material is not always uniform, but we will make it as near the above as possible."



SHED AND FEED YARDS USED FOR EXPERIMENTS



RACK FOR FEEDING ALFALFA HAY TO HOGS

APPENDIX

The Tables in the Appendix give the original data of the experiments. The Tables in the body of the bulletin were compiled from these.

WEEKLY DATA, PEN 1. 1906-07
(Ten head in each pen.)

Barley; alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Alfalfa Hay
Beginning	838	...	...	...	...
1st week	811	—2.7	—2.7	303	144
2nd week	937	126	12.6	390	90
3rd week	1025	88	8.8	406	54
4th week	1102	77	7.7	395	54
5th week	1156	54	5.4	395	76
6th week	1243	87	8.7	445	20
7th week	1390	147	14.7	473	60
8th week	1479	89	8.9	397	60
9th week	1530	51	5.1	430	60
10th week	1522*	102	10.2	420	60
11th week	1573	51	5.1	450	60
12th week	1694	121	12.1	485	20
13th week	1794	100	10.0	445	40
		1066§	106.6	5434	798

* piggy sow, weight 205 lbs., put out; 95 lb barrow put in.
§ 956 lbs. plus 110 lbs. lost by exchanging pigs.

WEEKLY DATA, PEN 2. 1906-07
(Ten head in each pen.)

Corn; alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Corn	Alfalfa Hay
Beginning	669	...	...	...	...
1st week	823	154	15.4	303	144
2nd week	896	73	7.3	384	90
3rd week	995	99	9.9	406	54
4th week	1066	71	7.1	420	54
5th week	1125	59	5.9	420	76
6th week	1202	77	7.7	450	60
7th week	1310	108	10.8	483	60
8th week	1393	83	8.3	467	60
9th week	1477	84	8.4	470	60
10th week	1548	71	7.1	440	60
11th week	1622	74	7.4	530	80
12th week	1737	115	11.5	565	40
13th week	1814	77	7.7	475	40
		1145	114.5	5813	878

WEEKLY DATA, PEN 3. 1906-07

(Ten head in each pen.)

Barley and corn, equal parts, and alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS. Barley	Corn	Alfalfa Hay
Beginning	688	...	...	...	...	...
1st week	796	108	10.8	152	152	144
2nd week	894	98	9.8	176	176	90
3rd week	992	98	9.8	190	190	54
4th week	1084	92	9.2	189	210	54
5th week	1145	61	6.1	193	210	76
6th week	1230	85	8.5	248	210	60
7th week	1368	138	13.8	230	230	60
8th week	1474	106	10.6	210	210	60
9th week	1549	75	7.5	240	240	60
10th week	1661	112	11.2	220	240	60
11th week	1737	76	7.6	290	280	80
12th week	1868	131	13.1	260	250	40
13th week	1991	123	12.3	240	250	40
		1303	130.3	2838	2848	878

WEEKLY DATA, PEN 4. 1906-07

(Ten head in each pen.)

Barley and wheat, equal parts.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS. Barley	Wheat
Beginning	671	...	...	...	...
1st week	788	117	11.7	152	152
2nd week	879	91	9.1	187	187
3rd week	970	91	9.1	192	192
4th week	1034	64	6.4	167	208
5th week	1103	69	6.9	193	210
6th week	1193	90	9.0	241	210
7th week	1313	120	12.0	235	210
8th week	1395	82	8.2	191	210
9th week	1460	65	6.5	239	230
10th week	1544	84	8.4	220	210
11th week	1621	77	7.7	250	260
12th week	1729	108	10.8	240	250
13th week	1824	95	9.5	195	250
		1153	115.3	2702	2779

WEEKLY DATA, PEN 5. 1906-07

(Ten head in each pen.)

Barley and peas, equal parts.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Peas
Beginning	687	...	...	...	...
1st week	812	125	12.5	140	140
2nd week	879	67	6.7	161	161
3rd week	988	109	10.9	180	180
4th week	1062	74	7.4	166	210
5th week	1121	59	5.9	167	210
6th week	1103*	59	5.9	235	210
7th week	1241	138	13.8	249	210
8th week	1333	92	9.2	210	210
9th week	1402	69	6.9	247	230
10th week	1509	107	10.7	246	240
11th week	1588	79	7.9	240	240
12th week	1686	98	9.8	250	250
13th week	1722	36	3.6	182	182
		1112 §	111.2	2673	2673

* 147 lb. pig taken out; 70 lb. pig put in.
§ 1035 lbs. plus 77 lbs. lost in exchanging pigs.

WEEKLY DATA, PEN 6. 1906-07

(Ten head in each pen.)

Barley and shorts, equal parts.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Shorts
Beginning	665	...	...	...	...
1st week	772	107	10.7	152	152
2nd week	873	101	10.1	176	176
3rd week	974	101	10.1	180	180
4th week	1049	75	7.5	210	210
5th week	1138	89	8.9	202	210
6th week	1195	57	5.7	203	210
7th week	1322	127	12.7	194	210
8th week	1396	74	7.4	190	210
9th week	1464	68	6.8	249	210
10th week	1582	118	11.8	222	210
11th week	1619	37	3.7	240	250
12th week	1765	146	14.6	220	210
13th week	1833	68	6.8	230	250
		1168	116.8	2668	2688

WEEKLY DATA, PEN 7. 1906-07
(Ten head in each pen.)

Barley and tankage, nine to one.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Tankage
Beginning	688	...	...	...	...
1st week	786	98	9.8	252	28
2nd week	898	112	11.2	324	36
3rd week	1035	137	13.7	400	44.4
4th week	1148	113	11.3	389	47.6
5th week	1188	40	4.0	393	50
6th week	1319	131	13.1	426	50
7th week	1430	111	11.1	511	50
8th week	1533	103	10.3	398	50
9th week	1610	77	7.7	433	50
10th week	1721	111	11.1	400	45
11th week	1768	47	4.7	450	45
12th week	1925	157	15.7	495	50
13th week	1987	62	6.2	395	50
		1299	129.9	5266	596

WEEKLY DATA, PEN 8. 1906-07
(Ten head in each pen.)

Corn and tankage, nine to one.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Corn	Tankage
Beginning	686	...	...	...	...
1st week	778	92	9.2	252	28
2nd week	889	111	11.1	324	36
3rd week	1005	116	11.6	400	44.4
4th week	1126	121	12.1	423	47.6
5th week	1190	64	6.4	392	50
6th week	1210*	117	11.7	432	50
7th week	1351	141	14.1	453	50
8th week	1444	93	9.3	362	50
9th week	1516	72	7.2	457	50
10th week	1652	136	13.6	435	45
11th week	1707	55	5.5	495	45
12th week	1869	162	16.2	540	50
13th week	2006	137	13.7	510	50
		1417§	141.7	5475	596

* 162 lb. pig taken out and 65 lb. pig put in.
§ 1320 lbs. plus 97 lbs. lost by exchanging pigs.

WEEKLY DATA, PEN 9. 1906-07

(Ten head in each pen.)

Beets and barley, at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Barley	Beets
Beginning	686	...	...	...	...
1st week	737	51	5.1	160	320
2nd week	838	98	9.8	219	438
3rd week	921	86	8.6	320	640
4th week	1006	85	8.5	284	700
5th week	1056	50	5.0	336	350
6th week	1125	69	6.9	408	300
7th week	1205	80	8.0	359	300
8th week	1276	71	7.1	343	300
9th week	1337	61	6.1	373	300
10th week	1403	66	6.6	350	250
11th week	1440	37	3.7	460	250
12th week	1537	97	9.7	460	150
13th week	1626	89	8.9	390	200
		940	94.0	4462	4498

WEEKLY DATA, PEN 10. 1906-07

(Ten head in each pen.)

Beets and corn, at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Corn	Beets
Beginning	680	...	...	...	...
1st week	776	96	9.6	160	320
2nd week	848	72	7.2	219	438
3rd week	921	73	7.3	320	640
4th week	981	60	6.0	350	700
5th week	1044	63	6.3	350	150
6th week	1090	46	4.6	400	300
7th week	1158	68	6.8	425	300
8th week	1221	63	6.3	349	300
9th week	1297	76	7.6	426	300
10th week	1351	54	5.4	385	250
11th week	1390	39	3.9	440	250
12th week	1478	88	8.8	440	150
13th week	1543	65	6.5	435	200
		863	86.3	4699	4298

TABLE C.

TOTAL FEED, WEIGHTS AND GAINS, ALL PENS, 1906-07

(13 weeks. 10 pigs in each pen.)

PEN NO.	INITIAL WEIGHT	CLOSING WEIGHT	GAIN	TOTAL FEED CONSUMED								NUTRITIVE RATIO
				Corn	Barley	Shorts	Peas	Wheat	Beets	Tankage	Alfalfa Hay	
I.	838	1794	1066*	----	5434	----	----	----	----	----	798	7.80
II.	669	1814	1145	5813	----	----	----	----	----	----	878	7.90
III.	688	1991	1303	2848	2838	----	----	----	----	----	878	7.81
IV.	671	1824	1153	----	2702	----	----	2779	----	----	----	8.05
V.	687	1722	1112§	----	2673	----	2673	----	----	----	----	4.27
VI.	665	1833	1168	----	2668	2688	----	----	----	----	----	6.55
VII.	688	1987	1299	----	5266	----	----	----	----	596	----	5.98
VIII.	686	2006	1417‡	5475	----	----	----	----	----	596	----	6.40
IX.	686	1626	940	----	4462	----	----	----	4498	----	----	11.23
X.	680	1543	863	4699	----	----	----	----	4298	----	----	11.54

* 110 lbs. credit. See weekly data.
§ 77 lbs. credit. See weekly data.
‡ 97 lbs. credit. See weekly data.

TABLE D.

ANALYSES OF FEEDS, 1906-07

	Dry Matter	Protein	Crude Fibre	Nitrogen Free Extract	Ether Extract
3. Barley	93.465	11.372	7.795	70.713	1.95
3. Peas	93.325	21.743	3.580	63.822	1.345
1. Alfalfa Hay	93.39	16.11	37.24	28.90	1.18
2. Sugar Beets	98.338	8.578	8.515	75.398	0.378
3. Denver Tankage	97.265	46.744	2.730	7.308	13.078
4. Swift's Tankage	93.75	42.15	6.95	15.50	16.30
4. Armour's Tankage	90.95	39.10	10.90	8.60	11.70

1. Analysis obtained from Colorado Bulletin No. 35, page 31.
2. Analysis obtained from Colorado Bulletin No. 46, page 37.
3. Analysis by Douglas of C. A. C.
4. Analysis from Iowa Bulletin No. 65, (1902). Given for comparison.

TABLE E.

* PERCENTAGE DIGESTIBLE NUTRIENTS IN FEEDS, 1906-07

	DIGESTIBLE NUTRIENTS			
	Dry Matter	Protein	Carbo-Hydrates	Ether Extract
Corn	89.1	7.9	66.7	4.3
Wheat	89.5	10.2	69.2	1.7
Barley	80.4	7.96	68.9	1.7
Peas	81.2	18.0	36.1	0.74
Shorts	88.2	12.2	50.0	3.8
‡Denver Tankage	90.4	43.5	5.0	12.8
Alfalfa Hay	56.03	11.92	35.09	0.46
§Sugar Beets	87.5	5.3	75.9	0.19

* Co-efficients taken from "Feeds & Feeding," by Henry.

‡ Percentages (Meat Scrap), "Feeds & Feeding," by Henry. Carbo-Hydrates estimated at 50%.

§ Percentage of crude fibre and ether extract digestible estimated at 50%.

TABLE F. (Compiled from preceding tables.)

FEED AND DIGESTIBLE NUTRIENTS CONSUMED BY ALL PENS. 13 WEEKS, 1906-07

PEN NO.	TOTAL FEED				TOTAL DIGESTIBLE NUTRIENTS			
	Total Grain	Hay	Beets	Tankage	Protein	Carbo-Hydrates	Ether Extract	Nutritive Ratio
I	5434	798	....	...	528	4024	96.0	7.8
II	5813	878	....	...	564	4185	254.0	7.9
III	5686	878	....	...	556	4162	174.9	7.81
IV	5481	...	....	...	498	3785	93.2	8.05
V	5346	...	....	...	694	2807	65.2	4.27
VI	5376	...	....	...	542	3196	147.8	6.55
VII	5266	...	....	596	678	3658	165.8	5.98
VIII	5475	...	....	596	692	3682	311.7	6.40
IX	4462	...	4498	...	593	6488	84.4	11.28
X	4699	...	4298	...	598	6396	210.2	11.54

WEEKLY DATA, PEN 1. 1907-08

(Eight head in pen.)

Ration: Barley 3 parts, corn 3 parts, alfalfa hay at pleasure.

	Weight Lbs.	Gain Lbs.	Average Gain per head Lbs.	FEED LBS.		
				Barley	Corn	Alfalfa Hay
Beginning	484	..	...	..	..	..
1st week	543	59	7.38	83	83	28
2nd week	610	67	8.38	105	105	34
3rd week	666	56	7.00	117	117	39
4th week	745	79	9.88	132	132	44
5th week	793	48	6.00	143	143	47
6th week	850	57	7.13	143	143	40
7th week	921	71	8.88	150	150	42
8th week	972	51	6.38	150	150	36
9th week	1034	62	7.75	162	162	40
10th week	1101	67	8.38	162	162	30
11th week	1152	51	6.38	172	172	34
12th week	1200	48	6.00	195	195	30
13th week	1280	80	10.00	195	195	28
14th week	1368	88	11.00	200	200	25
15th week	1415	47	5.88	200	200	22
		931	116.00	2309	2309	519

WEEKLY DATA, PEN 2. 1907-08

(Eight head in pen.)

Ration: Barley 3 parts, corn 3 parts, tankage 1 part.

	WEIGHT LBS.	GAIN LBS.	AVERAGE GAIN PER HEAD LBS.	FEED LBS.		
				Barley	Corn	Tankage
Beginning	487	...	....	...	...	..
1st week	520	33	4.13	83	83	28
2nd week	634	114	14.25	105	105	34
3rd week	700	66	8.25	117	117	39
4th week	775	75	9.38	132	132	47
5th week	850	75	9.38	143	143	47
6th week	962	112	14.00	144	144	48
7th week	1081	119	14.88	150	150	50
8th week	1158	77	9.63	150	150	50
9th week	1262	104	13.00	162	162	54
10th week	1376	114	14.25	162	162	54
11th week	1475	99	12.38	172	172	57
12th week	1569	94	11.75	195	195	65
13th week	1660	91	11.38	195	195	65
14th week	1752	92	11.50	198	198	66
15th week	1855	103	12.88	204	204	68
		1368	171.00	2312	2312	769

WEEKLY DATA, PEN 3. 1907-08

(Eight head in pen.)

Ration: Barley 6 parts, tankage 1 part.

	WEIGHT LBS.	GAIN LBS.	AVG. GAIN PER HEAD LBS.	FEED LBS.	
				Barley	Tankage
Beginning	485	...	....	...	..
1st week	531	46	5.75	166	28
2nd week	636	105	13.13	210	34
3rd week	696	60	7.50	234	39
4th week	775	79	9.88	264	44
5th week	852	77	9.63	286	47
6th week	920	68	8.50	288	48
7th week	1027	107	13.38	300	50
8th week	1100	73	9.13	300	50
9th week	1222	122	15.25	324	54
10th week	1319	97	12.13	324	54
11th week	1400	81	10.13	344	57
12th week	1470	70	8.75	390	65
13th week	1578	108	13.50	390	65
14th week	1672	94	11.75	396	66
15th week	1745	73	9.13	408	68
		1260	158.00	4624	769

WEEKLY DATA, PEN 4. 1907-08

(Eight head in pen.)

Ration: Corn 6 parts, tankage 1 part.

	Weight Lbs.	Gain Lbs.	Average Gain Per Head Lbs.	FEED LBS.	
				Corn	Tankage
Beginning	486	...	....	...	..
1st week	510	24	3.00	166	28
2nd week	600	90	11.25	210	34
3rd week	679	79	9.88	234	39
4th week	736	57	7.13	264	44
5th week	826	90	11.25	286	47
6th week	922	96	12.00	288	48
7th week	1026	104	13.00	300	50
8th week	1112	86	10.75	300	50
9th week	1219	107	13.38	324	54
10th week	1332	113	14.13	324	54
11th week	1425	93	11.63	344	57
12th week	1510	85	10.63	390	65
13th week	1617	107	13.38	390	65
14th week	1704	87	10.88	396	66
15th week	1795	91	11.38	408	68
		1309	164.00	4624	769

WEEKLY DATA, PEN 5. 1907-08

(Eight head in pen.)

Ration: Durum wheat 6 parts, tankage 1 part.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs.	FEED LBS.	
				Durum Wheat	Tankage
Beginning	484	...	....	...	..
1st week	515	31	3.88	166	28
2nd week	598	83	10.38	210	34
3rd week	692	94	11.75	234	39
4th week	760	68	8.50	264	44
5th week	856	96	12.00	286	47
6th week	892	36	4.50	288	48
7th week	1013	121	15.13	300	50
8th week	1123	110	13.75	300	50
9th week	1218	95	11.88	324	54
10th week	1315	97	12.13	324	54
11th week	1433	118	14.75	344	57
12th week	1492	59	7.38	390	65
13th week	1602	110	13.75	390	65
14th week	1673	71	8.88	396	66
15th week	1770	97	12.13	408	68
		1286	161.00	4624	769

WEEKLY DATA, PEN 6. 1907-08

(Eight head in pen.)

Ration: Durum wheat 3 parts, corn 3 parts, tankage 1 part.

	Weight Lbs.	Gain Lbs.	Average Gain per Head Lbs,	FEED LBS.		
				Durum Wheat	Corn	Tankage
Beginning	487	...	....	...	...	..
1st week	533	46	5.75	83	83	28
2nd week	606	73	9.13	105	105	34
3rd week	692	86	10.75	117	117	39
4th week	767	75	9.38	132	132	44
5th week	857	90	11.25	143	143	47
6th week	950	93	11.63	144	144	48
7th week	1066	116	14.50	150	150	50
8th week	1158	92	11.50	150	150	50
9th week	1262	104	13.00	162	162	54
10th week	1370	108	13.50	162	162	54
11th week	1469	99	12.38	172	172	57
12th week	1552	83	10.38	195	195	65
13th week	1644	92	11.50	195	195	65
14th week	1768	124	15.50	198	198	66
15th week	1870	102	12.75	204	204	68
		1383	173.00	2312	2312	769

TABLE III.

TOTAL FEED, WEIGHTS AND GAINS, ALL PENS 1907-08

(15 weeks, 8 pigs in each lot.)

PEN NO.	Weight at Beginning	Weight at Close	Gain in Weight	TOTAL FEED CONSUMED					Nutritive Ratio
				Barley	Corn	Durum Wheat	Tankage	Alfalfa Hay	
I.	484	1415	931	2309	2309	....	...	519	8.10
II.	487	1855	1368	2312	2312	....	769	...	5.33
III.	485	1745	1260	4624	....	....	769	...	5.19
IV.	486	1795	1309	....	4624	....	769	...	5.47
V.	484	1770	1286	....	....	4624	769	...	4.54
VI.	487	1870	1383	....	2312	2312	769	...	4.97

TABLE IV.

ANALYSES OF FEEDS, 1907-1908

	Dry Matter	Protein	Crude Fibre	Nitro-Free Extract	Ether Extract
Barley	93.465	11.372	7.795	70.713	1.95
Durum Wheat	90.189	10.394	2.746	71.185	2.217
Selected Tankage......	97.265	46.744	2.730	7.308	13.078
Alfalfa Hay..........	93.39	16.11	37.24	28.90	1.18

TABLE V.

PERCENTAGE DIGESTIBLE NUTRIENTS IN FEEDS, 1907-1908 *

	Dry Matter	Protein	Carbo-Hydrates	Ether Extract
Barley	80.4	7.96	68.9	1.7
Corn §	89.1	7.9	66.7	4.3
Durum Wheat	89.5	10.2	69.2	1.7
Selected Tankage †	90.4	43.5	5.0	12.8
Alfalfa Hay	56.03	11.92	35.09	0.46

* Coefficients obtained from Henry's "Feeds and Feeding."
§ Coefficients used from common wheat.
‡ Percentages used from meat scraps.

TABLE VI. (Compiled from preceding tables.)

FEED AND DIGESTIBLE NUTRIENTS CONSUMED, 1907-1908

(All pens, 15 weeks.)

PEN NO.	TOTAL FEED			TOTAL DIGESTIBLE NUTRIENTS			
	Total Grain	Hay	Tankage	Protein	Carbo-Hydrates	Ether Extract	Nutritive Ratio
I.	4618	519	..	427	3313	140.90	8.10
II.	4624	...	769	702	3173	237.14	5.33
III.	4624	...	769	703	3224	177.03	5.19
IV.	4624	...	769	701	3122	297.25	5.47
V.	4624	...	769	807	3238	177.04	4.54
VI.	4624	...	769	754	3180	237.04	4.97

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

Information Concerning the Colorado Carriage Horse Breeding Station

BY

JOHN O. WILLIAMS

PUBLISHED BY THE EXPERIMENT STATION
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Information Concerning the Colorado Carriage Horse Breeding Station

By JOHN O. WILLIAMS

This circular is not intended as a publication of any results attained in the carriage horse breeding experiment, but is intended as a *circular of information* so that interested persons may acquaint themselves with the object of the experiment conducted at the Colorado Breeding Station and the conditions by which they may avail themselves of the services of the various stallions in use at the station.

HISTORY AND OBJECT OF EXPERIMENT.

On July 1. 1904 an appropriation of $25,000 by Congress became available to the U. S. Bureau of Animal Industry for experiments in animal breeding and feeding in cooperation with the State Experiment Stations. Under this Act, carriage horse breeding was inaugurated in cooperation with the Colorado Experiment Station.

The first purchase of foundation stock was made in December, 1904 from George D. Rainsford, Diamond, Wyoming, and comprised six mares of excellent breeding and good carriage conformation. The next purchase was made in February, 1905 and included the standard-bred stallion "Carmon" 32917 (formerly shown as Glorious Thundercloud) and twelve trotting-bred mares of superior merit as show animals. These mares were bred in the various middle-western states and in Kentucky. The next purchase was made in June, 1906 and included the two saddle-bred mares Beatrice 2079 (S) and Mambrina 2400 (S). The last purchase was made in March, 1908 and comprised four mares from various breeders in Kentucky. These mares were Golden Picture 2788 (S); Bethel Princess 4796 (S); Barthenia McCord 4223 (S), and Elvira Lindsey 3083 (S).

The above named animals constitute the foundation animals of the experiment. The progeny of the foundation mares are carefully selected, and those adhering closely to the desired type are retained for breeding purposes. New blood will also be introduced from time to time through mating the offspring of the foundation mares to stallions other than those in use at the station, as well as through the purchase of additional animals.

The object of the work is to study the possibilities of evolving an American carriage horse from the American trotter, Morgan, and American saddle horse. The trotter is being used as the basis of the work and the two other native-blood lines are being used to supply the desired qualities they are known to possess. Through judicious blending of these blood lines, the ultimate American

carriage horse will be realized. This does not mean that animals which will fill the requirements are not already available as many specimens of "native" breeding have demonstrated their high carriage qualities by defeating the best imported animals in competition in the show ring. The encouragement for the retention of these outstanding individuals for breeding purposes is one of the admirable objects of the work by the department.

The qualities desired in a high class carriage horse are substance, quality, stamina or endurance, high-balanced action, good temperament and speed. The latter qualification is very desirable in most cases, but not in itself essential in the production of either a marketable or high-class carriage individual.

In order to present the desired qualifications of a carriage horse to the breeders, and also to encourage the production of a uniform type of carriage horse, the U. S. Department of Agriculture in cooperation with the American Association of Trotting Horse Breeders, has formulated a classification for American carriage horses which has been adopted by the various State Fairs throughout the United States. *

The classification is as follows:

TYPE.

The type desired for the American carriage horse is as follows: Not under 15 hands for mature horses; smooth, compact, and symmetrical conformation; neck of good length, inclined naturally to arch; sloping shoulders; well-set legs of medium length; sloping pasterns and good feet; short, strong back; well sprung ribs well ribbed up to coupling; smooth loins; full flanks; straight croup, with well-set tail; full round quarters.

CONDITIONS GOVERNING ENTRIES.

Classes open only to horses of American blood.

Stallions in classes 1 to 5, inclusive, must be registered either in the American Trotting Register as standard, in the American Morgan Register, or in the American Saddle Horse Register, and certificate of such registry must be shown in the ring if required.

Entries in all classes for mares must be registered either in the American Trotting Register as standard or non-standard, in the American Morgan Register, or in the American Saddle Horse Register, and certificate of such registry must be shown in the ring if required.

Entries as get of sire in class 5 and produce of mare in class 10, and entries in class 11 must be sired by a stallion registered as above, out of mares registered as above.

No mare having any draft cross will be eligible.

*From Twenty-Fourth Annual Report, B. A. I., U. S. Department of Agriculture.

Any exhibitor falsifying the breeding of entries will be barred.

Entries in all classes must be practically sound.

JUDGING.

Entries in all classes to be judged on conformation, style, action, and manners as a suitable type of carriage horse. Special attention will be given to trueness of action. Good knee and hock action are essential. Entries in all classes should trot and walk straight and true, and judges will especially avoid horses showing a tendency to pace, mix gaits, paddle in front or sprawl behind.

The following percentages will govern judges in classes 1, 2,

STUD NO. 1. CARMON 32917, AT 15 YEARS OF AGE.

Standard bred carriage stallion, shown as "Glorious Thundercloud." At the head of the Government stud at the Colorado Experiment Station.

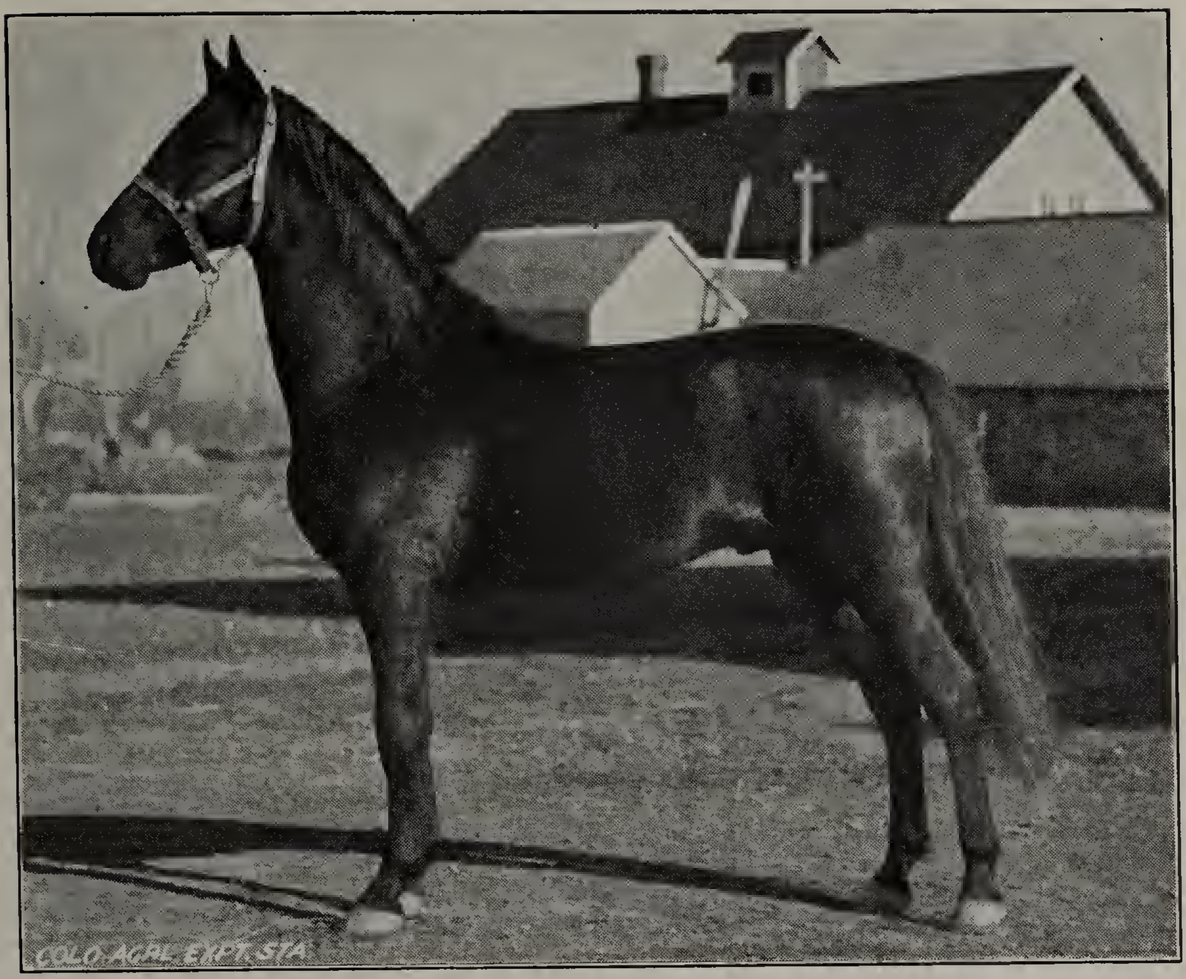
3, 4, 6, 7, 8, 9: General conformation and all-round suitability as a carriage type, 60 per cent; style, action, and manners, 40 per cent.

The following percentages will govern in class 5: General conformation and all-round suitability of sire as a carriage type, 30 per cent; style, action, and manners of sire, 20 per cent; general conformation and all-round suitability of get as a carriage type, taken as a whole, 30 per cent; style, action, manners, and uniformity of type in get, 20 per cent.

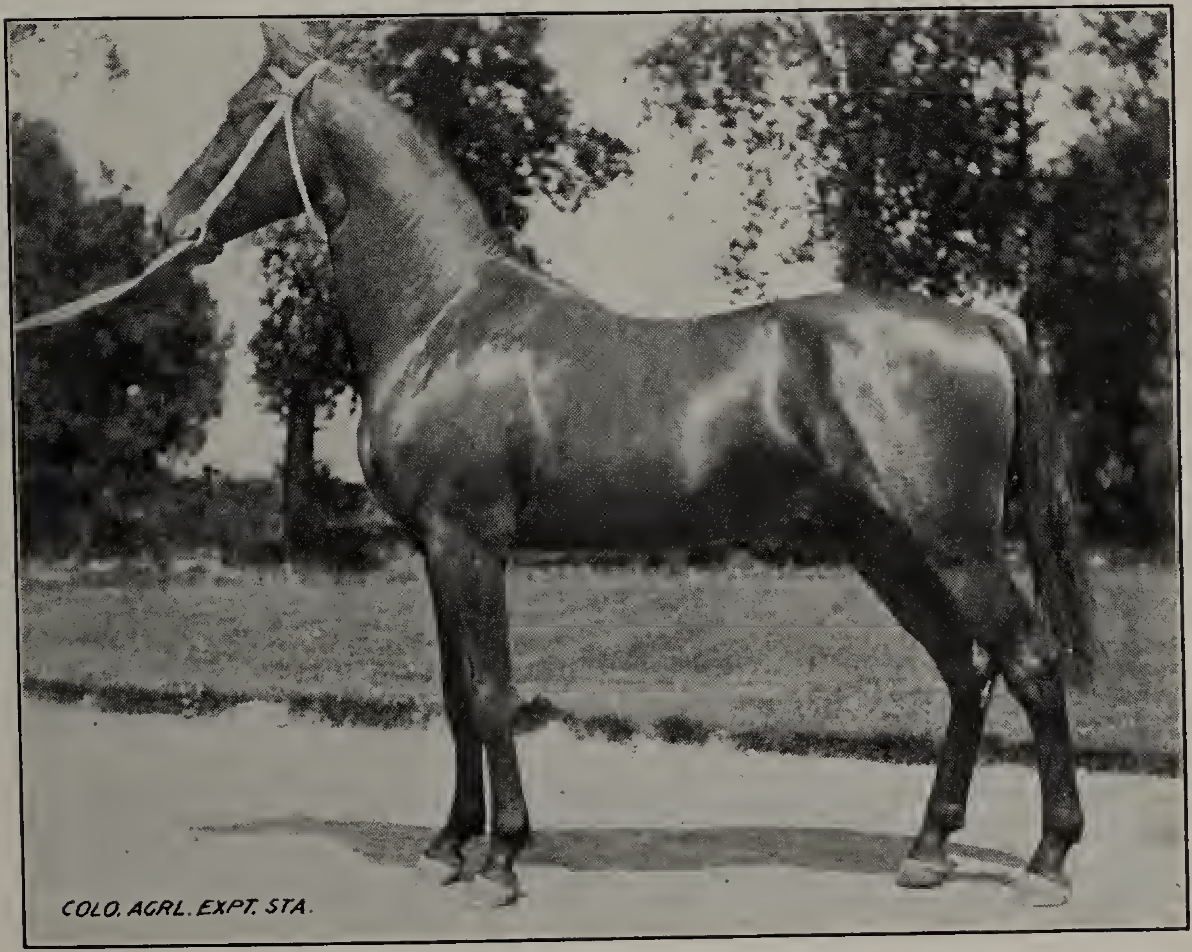
The following percentages will govern in class 10: General conformation of dam as a brood mare of the carriage type, 50 per

STUD NO. 37, ALBION, AT 4 YEARS OF AGE.

STUD NO. 39, ALVA, AT 4 YEARS OF AGE.



STUD NO. 40, BALFOUR, AT 3 YEARS OF AGE.



STUD NO. 46, CHESTER BOURBON 3577 (S), AT 2 YEARS OF AGE.

cent; general conformation, style, action, and manners of the foal, 50 per cent.

The following percentages will govern in class 11: General conformation of entry as a carriage type, 70 per cent; style, action, and manners, 30 per cent.

MANNER OF SHOWING.

Entries in classes 1, 2, 6, and 7 to be shown in harness, hitched to any suitable vehicle. Entries in all other classes to be shown in hand to bridle or halter. Excessive weight in shoeing in any class is forbidden.

CLASSES.

Class 1. Stallion 4 years old or over.
Class 2. Stallion 3 years old and under 4.
Class 3. Stallion 2 years old and under 3.
Class 4. Stallion 1 year old and under 2.
Class 5. Stallion with three of his get of either sex; get need not be owned by exhibitor.
Class 6. Mare 4 years old or over.
Class 7. Mare 3 years old and under 4.
Class 8. Mare 2 years old and under 3.
Class 9. Mare 1 year old and under 2.
Class 10. Mare and foal of either sex.
Class 11. Foal under 1 year old, either sex.

The above classification, if carefully studied, will give the breeder a definite idea of what is desirable in an American carriage horse. The classification is not intended to antagonize or conflict in any way with the classifications offered for individuals possessing the blood lines mentioned therein. The type desired is distinct from either those required in the American Trotter, American Saddle or Morgan classification.

SALE OF SURPLUS ANIMALS.

The animals used in connection with the breeding operations at the station, along with their offspring, are inspected annually by a Board of Survey consisting of Mr. Geo. M. Rommel, Chief of Animal Husbandry Division, U. S. Department of Agriculture; Professor C. F. Curtiss, Director of Iowa Experiment Station, and the officer in charge of the breeding establishment, with a view of determining the producing qualities of the various animals in the stud and the progress made during the preceding year. In the past the inspection has resulted in the elimination of some of the original herd of mares and many of the offspring produced at the station and placing them on sale to the public at auction. The animals eliminated from the stud in this manner are sold without reserve and also without obligation on the part of the station to the buyer after the animal is sold.

STALLIONS IN SERVICE.

The stallions described herein will be allowed to stand for public service to a limited number of approved mares.

CARMON—32917, Stud No. 1. *

The stallion Carmon is the foundation sire in service at the breeding station. He is a bright bay, standing 16 hands in height and weighs 1250 pounds. Carmon is a standard bred stallion of carriage type.

PEDIGREE OF CARMON

CARMON No. 32917. [Breed standard bred; sex, male; color, bay; height, 16 hands; weight, 1,250 pounds; date of birth, 1895. Breeder, Norman J. Colman, St. Louis, Mo. At Stud, Colorado Experiment Station, Fort Collins. Colo.	Carnagie No. 8405.	Robert McGregor No. 647.	Major Edsall No. 211.	Abdallah. No. 15.
				By Harris's Hambletonian No. 2.
			Nancy Whitman	American Star No. 14.
				Nance, by Young Messenger Duroc
		Annie Nutwood (non-standard) Vol. VI. p. 376, A. T. R.	Nutwood No. 600.	Belmont, No. 64
				Miss Russell by Pilot. jr., No. 12
			Annie Watson	Vermont Boy.

	Monitor Maid Vol. XI. p. 646, A. T. R.	Monitor No. 1327.	Merchant No. 599.	Belmont, No. 64.
				Lady Mambrino by Mambrino Chief No. 11.
			Trojana	Trojan. No. 312
				By Hercules
		Clara C. Vol. XI, p. 389, A. T. R.	Seth Warner No. 281.	Ethan Allen. No. 43.
				Sontag, by Harris's Hambletonian, No. 2.
			Grace	Abdallah, jr. No. 5720.
				Glencoe Belle, by Old Bull.

* In giving registry numbers the following system is used to indicate the register in which any given number appears: Those in the American Trotting Register are printed open, thus: Carmon 32917. Those in the American Saddle Horse Register are followed by a capital S in parenthesis, thus: Chester Bourbon 3577 (S). Thoroughbred horses are designated thus: (TH).

ALBION—Stud No. 37.

Albion is a bright bay stallion, standing 16:1 hands in height and weighing 1300 pounds. He was sired by Carmon and his dam, Arizona, was sired by Emigrant. His pedigree is as follows:

PEDIGREE OF ALBION

ALBION Stud No. 37 Sex, male, color, bright bay; height, 16.1 hands; weight, 1,300 pounds; date of birth, April 9, 1906; breeder, Colorado Exp. Station, Fort Collins, Colo.	Carmon No. 32917	Carnagie No. 8405	Robert McGregor, No. 647.	Major Edsall No. 211
				Nancy Whitman
			Annie Nutwood (non standard) Vol. VI., p. 376, A. T. R.	Nutwood No. 600
				Annie Watson
		Monitor Maid Vol. XI., p. 646, A. T. R.	Monitor No. 1327.	Merchant No. 599
				Trojana
			Clara C. Vol. XI., p. 389, A. T. R.	Seth Warner No. 281
				Grace
	Arizona Stud No. 17	Emigrant	Lord Winbeam	George Peabody by Hamiltonian No. 10

			Lady Spartan	Spartan by Ethan, Allen 43 (Morgan).

		Hoyden	Red Bud (Th)	Tom Bowling, by Lexington.
				Oleander, by Tipperary.
			Cora	Spartan Jr., by Spartan (Morgan)
				Lady Fanna

ALVA—Stud No. 39.

The stallion Alva is a bright bay in color, standing 15:1½ hands in height and weighing 1100 pounds. His pedigree is as follows:

PEDIGREE OF ALVA

ALVA Stud No. 39 Sex, male; color, bright bay; height, 15.1½ hands; weight, 1,100 pounds: date of birth, March 23, 1906; breeder, Colorado Exp. Station, Fort Collins, Colorado.	Carmon No. 32917	Carnagie No. 8405	Robert McGregor No. 647	Major Edsall No. 211
				Nancy Whitman
			Annie Nutwood (non-standard) Vol. VI., p. 376, A. T. R.	Nutwood No. 600
				Annie Watson ----
		Monitor Maid Vol. XI. p. 646, A. T. R.	Monitor No. 1327	Merchant No. 559
				Trojana
			Clara C. Vol. XI., p. 389, A. T. R.	Seth Warner No. 281
				Grace
	Washington Stud No. 2	C. H. Purcell, 2:19¼ No. 25226	Morgan Messenger	-------------- -----
			Clermont, 2:28¼	Red Wilkes, 1749, by Geo. Wilkes 519

BALFOUR—Stud No. 40.

Balfour is a dark bay stallion, standing about 15 hands in height and weighing 1025 pounds. He is a stallion of exceptional quality and action. His pedigree is as follows:

PEDIGREE OF BALFOUR

BALFOUR Stud No. 40. Sex, male; color, dark bay; height 15 h'ds; weight, 1,025; pounds; date of birth, April 19, 1907; breeder, Colorado Exp. Station, Fort Collins, Colo.	Carmon No. 32917	Carnagie No. 8405	Robert McGregor No, 647	Major Edsall No. 211
				Nancy Whitman
			Annie Nutwood (non-standard) Vol. VI., p. 376, A. T. R.	Nutwood No. 600
				Annie Watson
		Monitor Maid Vol. XI., p. 646, A. T. R.	Monitor No. 1327	Merchant No. 599
				Trojana
			Clara C. Vol. XI., p. 389, A. T. R.	Seth Warner No. 281
				Grace
	Dakota, Stud No. 7 (In service at Experiment'l Station)			

CHESTER BOURBON—3577 (S).

This stallion is a registered American Saddle stallion which will be placed in the stud during the season 1911 to a limited number of approved mares. This horse stands 15:2 hands, and weighs 1000 pounds as a two year old. His description and pedigree follows:

PEDIGREE OF CHESTER BOURBON

CHESTER BOURBON No. 3577 (S). Breed, American saddle; sex, male; color, bay; height, 15.2 hands; weight, 1,000 pounds; date of birth, May 5, 1908; breeder, A. G. Jones, North Middletown, Ky.	Bourbon King No. 1788 (S)	Bourbon Chief No. 976 (S)	Harrison Chief No. 1606 (S)	Clark Chief No. 89, A. T. R.
				Lute Boyd
			Belle	Latham'sDenmark No. 69
				Dau of Bellfounder
		Annie C No. 3025 (S)	King (Wilson's) No. 2196 (S)	Harrison Chief No. 1606 (S)
				Dau. of Parson's Abdallah
			Kate	Richlieu, he by Indian Chief 1718 (S)
				Kate by Kentucky Chief
	Barthenia McCord No. 3223 (S)	Chester Dare No. 10 (S)	Black Squirrel No. 58 (S)	Black Eagle No. 74 (S)
				Mollie No. 70 (S)
			Nannie Garett No. 472 (S)	Dave Akin (Th) No. 755 (S)
				Nannie
		Dau.	Peavine No. 85 (S)	Rattler
				Dau. of Wagner Jr. (Th.)
			Dau.	Trojan
				Dau. of Brinker's Drennon, 1600 (S)

The stallions herein named are in service at the station during the season of 1910. Other stallions will mature and be placed in service during each succeeding year, thereby adding to the number now in service.

TERMS OF SERVICE.

Private individuals can avail themselves of the services of the above named stallions under the following conditions:

1. The mares to be bred must be approved by the officer in charge.

2. Service fee must be paid at the time of first service, the amount for each stallion being given below. The groom is instructed not to furnish service unless authorized by the officer in charge.

3. Owners of mares will be allowed return privileges at any time during the breeding season of the same year in which the first service is given. The following fees will prevail until further notice:

Carmon	$25.00
Albion	15.00
Alva	10.00
Balfour	10.00
Chester Bourbon (will be placed in stud, 1911).	

4. The utmost care will be exercised to prevent any accidents while mares are in the custody of the Colorado Experiment Station, but neither the Station nor the Department will be responsible should any occur.

FACILITIES FOR KEEPING OUTSIDE MARES.

The Station is equipped to keep a limited number of mares belonging to private individuals. This arrangement is provided for those who send mares from a distance. Owners of mares living within a convenient distance of the Station cannot be provided with accommodations for their mares.

The following fees will be charged for mares kept at the Station:

For pasturage alone, 50 cents per week for each animal.

For paddock at Station (with hay and pasturage), $1.00 per week for each animal.

For box stall and stable accommodations, $1.50 per week for each animal.

If grain ration is desired, and additional charge of $1.00 per week for each animal will be charged.

Bulletin 167 September, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

A Too Common Farm Scene

LIFE AND CARE OF FARM MACHINERY IN COLORADO

BY

H. M. BAINER *and* H. B. BONEBRIGHT

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1910

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FORT COLLINS, COLORADO

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LIFE AND CARE OF FARM MACHINERY IN COLORADO

By H. M. BAINER and H. B. BONEBRIGHT

The twelfth census report of 1900 places the valuation of the agricultural implements on the farms of Colorado at $4,746,755.00. Knowing of the wonderful development of agriculture in Colorado within the past decade, a conservative estimate would not place the present valuation at less than $10,000,000.00.

In traveling over the state, the ordinary observer is unfavorably impressed with the methods now commonly found in use by our farmers for taking care of their machinery. As a general rule, the prosperity of the farmer may be estimated by the way he cares for his machinery. Poor care indicates shiftlessness, waste, lack of energy and the necessity of buying more machinery in a short time.

Plate 2. The profits from many Colorado farms are found in such "junk heaps" as this.

Good care, on the other hand, indicates prosperity, development, bank deposits, and long lived machinery.

At the present time there is a growing demand for information on the subject of the life and care of farm machinery in Colorado. With the idea of obtaining this information, the Farm Mechanics Department has carefully investigated the machinery conditions on over two hundred representative farms in all parts of the state. This information is summarized in the following remarks:

SELECTION OF MACHINERY.

Type.—The proper care of a farm machine begins in the careful and intelligent selection of the correct type of machine for the work which it is expected to do. This point is too often overlooked

by the man who is strongly prejudiced in favor of some particular make or so-called "line" of implements.

Size.—When the correct type of machine has been selected, its size should be carefully considered. By the use of sufficiently large and strong implements, with large capacity, a great deal of time and labor is saved and the life of the machine is greatly lengthened.

For example, on a fair sized field, a three section harrow will do one-half more work with the same amount of man labor. The teeth, having to travel less distance in harrowing the field, will remain sharp longer, and, consequently, the efficiency of the harrow is increased, while the time required for the work is decreased.

Three section harrows were found in operation on one-third of the enumerated farms of 80 acres and over. Three section harrows were used on but one-half of the enumerated farms of 160 acres and over, the remaining one-half using nothing larger than the two section harrow. In no case was a farmer found who had used a three section harrow and was willing to discard it for one of two sections.

A man of ordinary ability can handle a two bottom gang plow nearly as easily as a sulky, or one bottom plow. By the use of the gang the capacity of man and plow are doubled, while the wear on each plow is only one-half what it would be on the single plow, were it made to cover the same number of acres as the gang. Then too, time is saved in case the shares must be taken to a shop for sharpening, as only one-half as many trips are necessary for the gang as with the single plow, for a field of equal size.

Gang plows, ranging from two to four bottoms, are now being used on less than nine per cent of the farms of 80 acres or more which have been investigated. In communities where suitable gang plows have been tried, the demand for them is increasing.

In some cases, such as gardening, special farming deep work, etc., it is often not advisable to try to cover too much ground at once. Again, some of our special implements are made only in single units, such as the modern two-way plow. This plow has many advantages that will often justify its use in place of the two and four bottom gang plows.

Accessibility to Repairs.—In selecting machinery, it is usually advisable to consider the matter of securing repairs. Repairs or new parts must be secured for nearly every farm implement some time, or perhaps several times, during the life of it. Usually, the repairs are not ordered until the implement will not run any longer without them and then they must be secured in a hurry. For example, the binder, mower, or other important implements or machines must be repaired at once, or the farmer may lose part of his

crop while waiting for repairs. In this case, the question of being able or unable to secure the necessary repairs, may represent the difference between loss and gain on the season's crop. For such implements as are absolutely necessary during certain seasons, the owner should be able to get repairs on not over one day's notice, if not at once. Instances were found where the farmer was compelled to buy a new machine of another make simply because he was unable to ge a repair for his old machine in time to do the necessary work.

Oiling Devices.—Good visible oiling devices should be found on every farm machine. In selecting machinery this point should be kept in mind, as the life of the machine depends to a considerable extent upon whether or not it can be kept thoroughly oiled. Often all the necessary oiling provisions are made, but they are not in as plain sight as they should be and for this reason are likely to be overlooked.

Again, the oil holes should be well protected from dirt, and should also be easy to clean. Fast running machinery and that which needs oil constantly should be provided with good, self feed-

Plate 3. Machinery loses much of its value if kept in an agent's back yard for several years.

ing oil cups. Hard oilers have proven very satisfactory, especially where the parts are subjected to a great deal of dirt and there is no question but that they should be used even more than they are at present.

Thoroughly Painted.—The new implement or vehicle, as it comes from the dealer, should show a good grade of paint. This is especially true of buggies and wagons. The paint should show that it has been applied in smooth thin layers, which have been well rubbed down, and should not show a tendency to clottiness or scaliness. The paint should be covered with a good coat of varnish.

The character of the implement or vehicle is reflected to a

certain extent by the paint which covers it. Certain implements are known by their good paint, others are known by their poor paint.

New Machinery.—In buying new machinery or implements, the farmer should see to it, that he is not paying the price of a new machine for one that stood in an open back yard of some implement dealer, from one to three years. This is often the case and there is no good excuse for it from either the standpoint of the dealer or the farmer.

In the first place, the dealer should not allow his new machinery to stand in the open for long periods, and thus let it become weather beaten and damaged. In the second place, the farmer should not buy this damaged machinery at new machinery prices. He must consider that an implement is damaged as much by standing out one year, as it would be by actually using it one season.

PROPER ADJUSTMENT AND REPAIRS.

Adjustments.—Nearly every one understands the importance of making proper adjustments on farm machinery. A large percentage of the machines found in the field are badly out of adjustment. In many cases the improperly adjusted machines do such inferior work that they are discarded long before they are worn out.

For example, on one of the farms investigated, a binder, of reliable make, was found which had cut but ten acres before being discarded eight years ago, simply because the operator was unable to properly time the binder driving gear, after he had removed the cog wheel to replace a defective spring. The same make and type of binder has been in active operation on another investigated farm for the past twelve years. It has cut at least nine hundred acres and is still in first class condition.

The improper adjustment of one part of a machine often leads to the ruination of several other parts, much time of man, team and machine is lost "tinkering" with improperly adjusted machinery. In a large percentage of cases, the draft of the implement is unnecessarily increased because of improper adjustment. Not only is the draft increased, but it is not uncommon to find side draft produced in the machine as a result of improper adjustment.

The loss due to the discarding of machines before they are worn out, the inferior work, the damage to teams from excessive draft and side draft, and the valuable time lost in "tinkering" always justifies the spending of sufficient time to put the farm machinery in proper adjustment before it is put into regular service. Many of these adjustments may be made long before the machine is needed.

Repairing Machines.—Every machine, in active operation will sooner or later need repairs. The operator should be able to forsee the need of a large part of the necessary repairs some time before

they are actually needed. Of course, in the case of parts that break unexpectedly, due to defects or accidents, the operator has a reasonable excuse for not forseeing the trouble. But in cases where parts are worn, or weakened, there is little excuse for not making repairs long before the machine is to be operated again. In some cases it may be desirable to operate the old part for some time after it is badly worn. Under such conditions, good judgment demands the keeping of the extra part on hand ready to be substituted when occasion demands. As a worn part often ruins some unworn part, it is often advisable to replace the badly worn part at once. The main gear on a binder is an excellent example of the last mentioned case. After the pinion becomes worn, it is likely to either cut out the gear wheel or slip cogs, thus endangering chains and other gears.

It is advisable to place a tag upon each machine at the end of the season, stating just what repairs and adjustments are needed, so that these may be secured or made during the time when work is not pressing.

The investigation, which was carried on in May and June, showed that out of 1,716 machines (not including any discarded machines) 60.6 per cent were not in need of repairs. 27.15 per cent were in need of repairs according to statements received on the farms. The investigator could easily see, without careful examination, that 18.6 per cent of the machines needed repairs that were not reported. On 109 or 6.35 per cent of the machines the investigation showed that repairs in addition to those reported on the farms were needed. (The discrepancy of 6.35 per cent is thus explained.)

Sharpening.—There is little doubt in the minds of experienced farmers but that dull implements do an inferior grade of work, and at the same time, they unnecessarily increase the draft.

In general, with the exception of the smoothing harrow, the implements investigated proved to be as sharp as could reasonably be expected. Plows, disc harrows, cultivators and weeders were found to be in first class condition so far as sharpening was concerned. On the other hand, the smoothing harrow, one of the most important of farm implements, was found to be too dull for good service in 77 per cent of the investigated cases. Nearly 7 per cent of the harrows were too nearly new to be badly dulled, while only 16 per cent of the harrows had had the teeth reversed or sharpened. In the records of the dry farming sections over 83 per cent of the harrows (not including new ones) were sharp. In a great many cases, all that was necessary was the reversing of the teeth in order to give all the advantage of the sharp harrow, yet in only a few cases had this been done.

The investigation discovered harrows which had been in use for twenty years, and which had covered 3,000 acres without being sharpened or reversed.

Plate 4. It costs no more to do good work with a sharp harrow than it does to slide over the ground with a dull one.

THE FARM WORK SHOP.

If the observer was to draw conclusions from the farms investigated, he would have to conclude that very few farmers realize the importance of the farm work shop. As a matter of fact, a great many of those farmers who do not own shops understand the advantage of them. Again, many farmers are under the impression that they haven't the "knack," which they believe is a necessary adjunct, if they are to do repair work. Many have not investigated the cost of a small shop outfit, neither have they figured the matter on a basis of dollars and cents.

In cases where farmers are not very handy to the local shop, the time which is lost while going to and from the distant shop often amounts to several times the actual charges. At critical times, such as harvesting or seeding seasons, one long trip to town for repairs may cause a loss more than equal to the value of a well equipped shop.

The following table shows that the machinery found on farms having well equipped shops is in need of less repairs than that on farms without shops:

	Farms without Shops	Farms with Shops
Percentage of machinery not needing repairs.....	59.25	71.36
Percentage of machinery needing repairs as reported by the farmer........................	27.7	22.4
Percentage of machinery needing repairs as reported by investigator and not by farmer......	20.2	6.24
Percentage of machinery reported by investigator needing repairs in addition to those reported by the farmer	7.15	0.0

The fact that machines are found in a better state of repair on the farms having well equipped shops goes to show very plainly that there is a real value to the shop beyond the occasional emergency job. These facts in themselves are strong arguments in favor of the farm shop. Of the farms investigated a little over 9 per cent were equipped with suitable shops.

Equipment.—In order to obtain the best results, the shop should be fitted with both carpenter and blacksmith tools. It should be handy to the place where the implements are stored, and some means of heating it in winter should be provided. A very serviceable farm carpenter equipment may be procured for less than $20.00 as follows:

One—grindstone and frame.
" —oil stone.
" —good square.
" —fine cross cut saw, at least 24 in. long.
" —rip saw at least 26 in. long.
" —compass saw.
" —claw hammer.
" —Jack plane.
one—¼-in. bit.
" —⅜-in. bit.
" —½-in. bit.
" —⅝-in. bit.
" —¾-in. bit.
" —1-in bit.
" —¼-in. firmer chisel.
" —½-in. firmer chisel.
" —1-in. framing chisel.

One good, adjustable brace, strong enough to operate drills as well as bits.

In case the shop equipment is to be more nearly complete, a coarse, cross-cut saw may be added. A full set of bits, including an expansion bit, may be substituted for the above list of bits and a full set of planes will be found handy at times. A carpenter's combined level and plumb will be useful as will also a wood bench vise. The bench is easily constructed upon the farm.

In the line of blacksmith tools a great deal of difference of opinion exists. A small forge and anvil usually prove satisfactory, although some insist on large forges and heavy expensive anvils. It is safe to say that a serviceable farm blacksmith equipment as listed below may be secured for $30.00.

One small, combined portable hand blower and forge.
Two pairs tongs.
One hardy.
One steel-faced anvil.
One set of screw plates and taps, in sizes ¼, 5/16, ⅜, 7/16, ½, ⅝ and ¾ inches.
One triangular file about 6 inches.
One round file 10 inches.
One flat plow file about 14 inches.
One blacksmith hammer.
One combined vise and drill press.

By using the tools furnished with the farm machinery, in connection with the above enumerated outfit, a great deal of very good repair work may be done.

In case more money is to be expended, a strong blacksmith's

Plate 5. A Small Farm Shop

vise and a separate drill press fitted with twist drills should be substituted in place of the combined outfit. A complete set of screw plates and taps, ranging from one-fourth inch to one inch will be found useful. A heavy blacksmith's hammer and sledge will also come in handy. On large ranches the tire shrinker soon pays for itself.

LUBRICATION.

One of the first steps toward properly oiling farm machinery is to select it with good oiling provisions as described under "Oiling Devices."

Someone says: "Oil is the cheapest machinery we have." It

is better to spend fifty cents for oil than to spend $5.00 for a new part.

Application.—Surfaces of the wearing parts of a bearing must be covered with a thin film of oil to prevent cutting and to lighten the draft.

A bearing does not have to be "swimming" in oil in order to be well lubricated, but oil should be applied often in small quantities and should reach the place which needs it. All oil holes must be kept open and free from dirt. Sometimes they become clogged, and while they may appear to be open, still they do not convey the oil to the wearing parts and a great deal of damage is done. Many machines have been condemned, simply because one or two oiling places have been entirely overlooked. Often, for lack of a few drops of oil, the entire machine is brought to a standstill.

Kind of Lubricant.—There are many good grades of machine oils or lubricants on the market. There are also many poor grades of lubricants which are adulterated with rosin or paraffine, and may appear to be of excellent quality, but they are too gummy and dry up in a short time. Good oils will cost a little more than the cheap oils, but the higher priced oils really cost less in the end.

For farm purpose oils may be classified into heavy oils, light oils, cup grease or hard oil and axle grease. These do not necessarily include gasoline engine and steam engine oils.

The heavy oils are thick or viscous and are adapted to use only in such places as drive at slow speeds and carry heavy weights, as axles of wagons. The heavy oil is not easily forced out of the bearings and it lasts longer.

Light oils or thin oils come in several grades. For ordinary farm machinery, a medium thin oil will answer a large share of the needs. For high speed, light running machinery, such as cream separators, a thinner oil is used than that advisable for ordinary farm machinery. This oil is not adapted to machinery that carries heavy loads as it will squeeze out of the bearings too easily.

Cup grease or hard oil has many qualities to recommend it. It remains on the bearing very well, and is easily applied and can be used in place of heavy and medium oils. It is usually applied through an automatic compression cup or a hand screw cap cup.

In using hard oil, dirt cannot enter the bearing with the oil, in fact, if any dirt enters the bearing from the end, the oil will force it out. Again, if the bearing should begin to heat, the oil will begin to melt and feed faster, if the grease cup is placed above the bearing.

For gasoline and steam engine cylinders, special cylinder oil must be used. Gasoline cylinder oil is lighter and thinner than

steam engine oil and is less expensive. The cylinder oils must be able to stand a great deal of heat. A good grade of ordinary machine oil will lubricate all parts of the engines, excepting the cylinders.

Oiling New Machinery.—On account of paint in the bearings of new machinery, the moving parts often run hard for the first few days. This paint can be easily removed by the application of kerosene or a mixture of equal parts of kerosene and machine oil, as the machine is being started.

CARE OF MACHINERY WHEN NOT IN USE.

To properly care for the farm machinery means that it must be well selected, kept in good repair and adjustment, oiled thoroughly, cleaned before housing, and it must have all wearing parts well greased when not in use, and painted when necessary, and it must be properly housed.

At least one-half of "good care" consists in keeping the machinery properly repaired, in good adjustment and thoroughly oiled when in use. To neglect any of the lines of care mentioned, means serious damage and loss to the machine.

The investigation showed that a small percentage of the farmers were taking the proper care of their machinery all the time. Certain farmers were found who gave their machinery excellent care when it was in use but it was given no care between seasons.

The investigation shows that there is a decided tendency to neglect the housing of machinery throughout the State. On but 22.15 per cent of the investigated farms was all the machinery housed. It was partly housed on 39.60 per cent of the farms, and on 38.25 per cent of the farms no attempt was made to house any of the machinery except the buggies, carriages and automobiles.

With the one exception of binder canvasses only 2.01 per cent of the farmers removed bright or delicate parts of their machinery for storage.

The fact that such a large percentage of the machinery is allowed to stand in the open is partly, but not wholly, explained by the marked scarcity of suitable machine sheds upon the farms.

Of the investigated farms only 19.46 per cent were equipped with closed machine sheds. 34.23 per cent had some form of open shed and 46.31 per cent had no machine sheds at all. In 74 per cent of the open sheds the machinery served as a hen roost while the chickens were allowed to roost in but 31 per cent of the closed sheds. Hogs, calves, etc., were allowed to run at will in 19.6 per cent of the open sheds and in only 10.3 per cent of the closed sheds. The fact that in 62.5 per cent of all the sheds investgated the machinery served as a hen roost, and in 15 per cent

of the total number of sheds the farm animals were allowed to run at will, will explain to a large extent why the housing of machinery apparently does so little good in Colorado.

In a large number of cases the housing consists of "going through the motions" rather than actually preparing the machinery for storage and then properly storing it in a suitable shelter.

MACHINERY SHOULD BE CLEANED AND OILED BEFORE STORING.

Whether the machinery is to be housed or not, it should be cleaned and thoroughly oiled at the end of the season. With such machinery as the binder or mower, it is a good plan to thoroughly oil all bearings and wearing parts just before finishing the season. After removing all dirt, wipe the entire machine with an oiled rag or waste. The wearing parts especially should be well greased with tallow or axle grease. If the entire machine is to be housed these wearing parts do not need to be removed from the machine, but they should be removed and stored in a dry place under all other conditions.

HOUSING THE MACHINERY.

To house machinery does not always do as much good as is commonly supposed. In making the investigation, the following question was asked many times: "How should farm machinery be cared for?" It is usually answered by the farmer: "Everyone knows that it should be housed." This is a good answer as far as it goes, but to house machinery under any condition, and not properly care for it otherwise, constitutes very poor care.

Machinery may be just as well cared for if it is allowed to stand in the shade of a tree, as if it is stored in some of the leaky sheds, open sheds, poorly drained sheds, or combined machine sheds and hen roosts, such as were found during the investigation.

There is no question but that to properly house machinery is a great saving, as it not only adds a great deal to the life of the machine but it also adds to the general appearance of the farm. It was generally found that where a farmer was interested enough in his machine to properly house it, he was also interested enough in it to care for it otherwise.

The investigation showed that the life of farm machinery depended a great deal upon the owner. Individual farmers were found who took very good care of their machinery and left it in the weather, when not in use; others were found who gave their machinery very poor care and housed it when not in use. A great deal of housed machinery was found which had done no more work and was no better or older than some which had not been housed but which had been well cared for otherwise.

Cultivator shovels, plow shears, and attachments, which have been removed and greased, should be placed where there is no

chance for them to get damp. It is a good plan to place them in a gunny sack and suspend them from the rafters of the shed or barn.

A great deal of farm machinery can be placed in a small space if properly arranged. At the time of storing the machinery, it should be placed in the shed according to the time it will have to be removed. The machinery that will be used late during the following season should be placed in the back part of the shed and that which is to be used early in the season should be placed in front. In this way, it will not be necessary to remove a great deal of machinery in order to get what is needed first.

The following illustration gives an idea of the amount of machinery which may be stored in a small shed if the man who stores it studies the problem thoroughly.

The following list of machinery was found in a two-story shed 20x30 feet. The shed has a small side door and a large double door at one end. On the first floor: A set of blacksmith tools with bench (repair work is done in the shed), riding plow, 2 cultivators, beet cultivator, binder, mower, grindstone, hay rake, grain drill, 2 smoothing harrows (2 sections each), slip scraper, and lister. On the second floor: A hay tedder (taken apart), several light tools, stoves (stored while not in use), some household goods, and other articles to numerous to mention. In case of large crops, grain is sometimes stored on the second floor of the shed.

The owner of the above described shed unhesitatingly states that the shed is plenty large enough for the implements on 160 acres, providing the wagon and buggy can be stored in some other building.

The time required for storing this machinery and removing it each year is estimated by the farmer to be one-half day for himself and hired man.

As the machinery is being stored, all that which needs repairs or paint should be labeled so that it cannot be overlooked during the time when the farm work is not crowding.

PAINTING FARM MACHINERY.

There is no question but that it pays to keep the farm machinery thoroughly painted. This is especially true with such machinery as is largely constructed of wood. The paint fills all pores and cracks, prevents checking, prolongs the life of the machine and also adds very much to its appearance. Two or three dollars' worth of a good, reliable, ready-mixed paint for outside use, or carriage paint, applied each year to the machinery found on the average sized farm will add many times the cost of the paint to the value of the machinery.

THE IMPLEMENT HOUSE.

It is not always necessary or advisable to construct a special building or storing farm machinery. Often a very good place can be made in the barn or other buildings. By taking some of the parts off of certain machines, they can be easily stored in what otherwise might be waste space.

The characteristics of a good implement shed are:

1. It must be thoroughly drained so the implements do not stand in a wet place.
2. It must protect against sun, wind and moisture.
3. It must not be too expensive.
4. It should be located in a convenient spot and so arranged as to be easily used.

The material from which the shed is made will depend upon the cost and the locality. In the investigation, very good sheds were found which were of wood frame construction, covered with sheet iron. Other good ones were found of wood frame construction, sided with barn siding, drop siding, and in some places with ship-lap. Shingles or corrugated iron generally make the best roofs for machine sheds.

Description of Shed Shown in Plates 6 and 7

This shed was built on a Colorado farm and has been in use for several years. The owner makes a practice of storing his machinery as it should be.

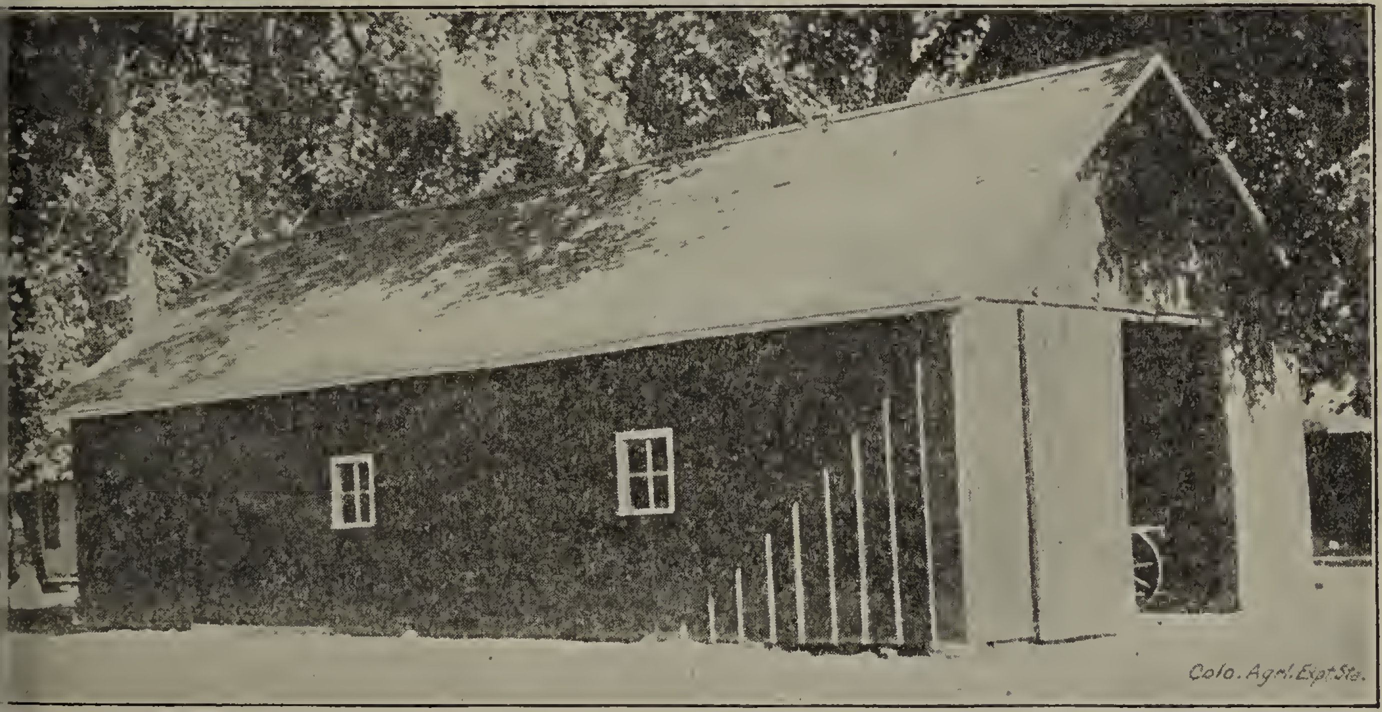

Plate 6. An Excellent Closed Machine Shed. For plans see Plate 7.

The shed is built upon posts which rest upon concrete bases 12 inches by 12 inches. A strong iron dowel pin set in the concrete and projecting up into the post keeps the latter from slipping. The sides of the shed are [illegible] feet high. The roof is one-third pitch, shingled. Rafters 2 in. x 6 in. x [illegible] ft. on center. The lower girt is 2 in. x 6 in., the middle girt (placed just below the windows) is 2 in. x 6 in., while the upper girt is 2 in x 8 in. and serves as plate.

As the posts do not extend into the ground, it is necessary to brace the sides and ends of the shed. Braces also extend from the side posts to the collar beams, where the rafters come nearly over the posts. On the south side at the west end is a rolling door 7 feet 6 inches high by 8 feet long. At the east end the opening is 8 feet high by 10 feet wide. It is covered by two rolling doors 5 feet by 8 feet.

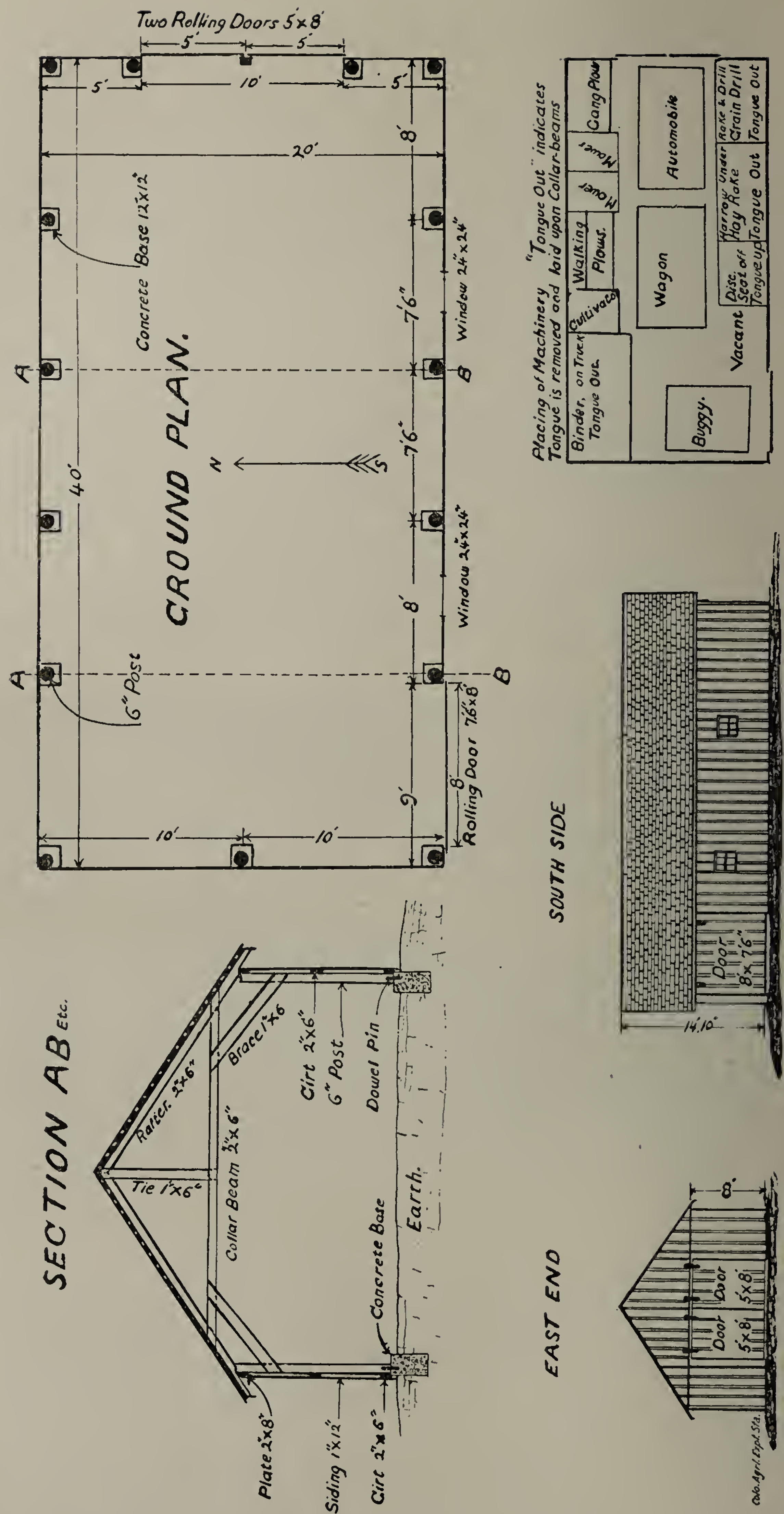

Plate 7. A Very Good Type of Closed Machine Shed

The sides are made of 12 inch stock boards. The cracks are covered ith O. G. battens. The ground upon which the shed sits is about a oot higher than the surrounding ground. This gives a hard, dry dirt oor for the machinery.

In the lower right hand corner of the drawing is shown the arrangeent of the machinery in the shed. In some cases (marked "tongue it") the tongues are removed from the machines and placed upon the ollar beams. The cultivator shovels, mower sickles, plow shears, binder anvasses, etc., are all greased and suspended from the collar beams. A rge part of the machinery may be removed by simply running out the ito. In some cases the wagon must also be removed. The transport ucks are almost a necessity for the storage of a binder in this sort of a ied. The shed is painted with two coats of mineral red in oil.

Description of Shed Shown in Plates 8 and 9

This shed has actually been built by a Colorado farmer and proves ery economical and satisfactory. The only changes in the original plan the addition of four small windows. The shed is 16x66 feet. The osts are 10 feet high in front and 8 feet high in the rear, and are set in ie ground 3 feet. There is no foundation for the shed.

Plate 8. A Well Planned Machine Shed. For plans see Plate 9.

These posts eliminate the necessity of a frame or braces. The botom girt is 2 in. x 6 in., the middle girt 2 in. x 4 in., and the top girt, hich also acts as plate, is 2 in. x 8 in. The rafters are 2 in. x 6 in., set feet apart on centers. The sheathing is 1 in. x 6 in. placed at the ıds and in the middle of the sheets of corrugated iron which form ıe roof. At each end on the front side of the shed is located a 12 foot olling door 8 feet high. Near the middle of the shed is a 14 foot door feet high. These doors roll upon a continuous track which runs the ıtire length of the shed.

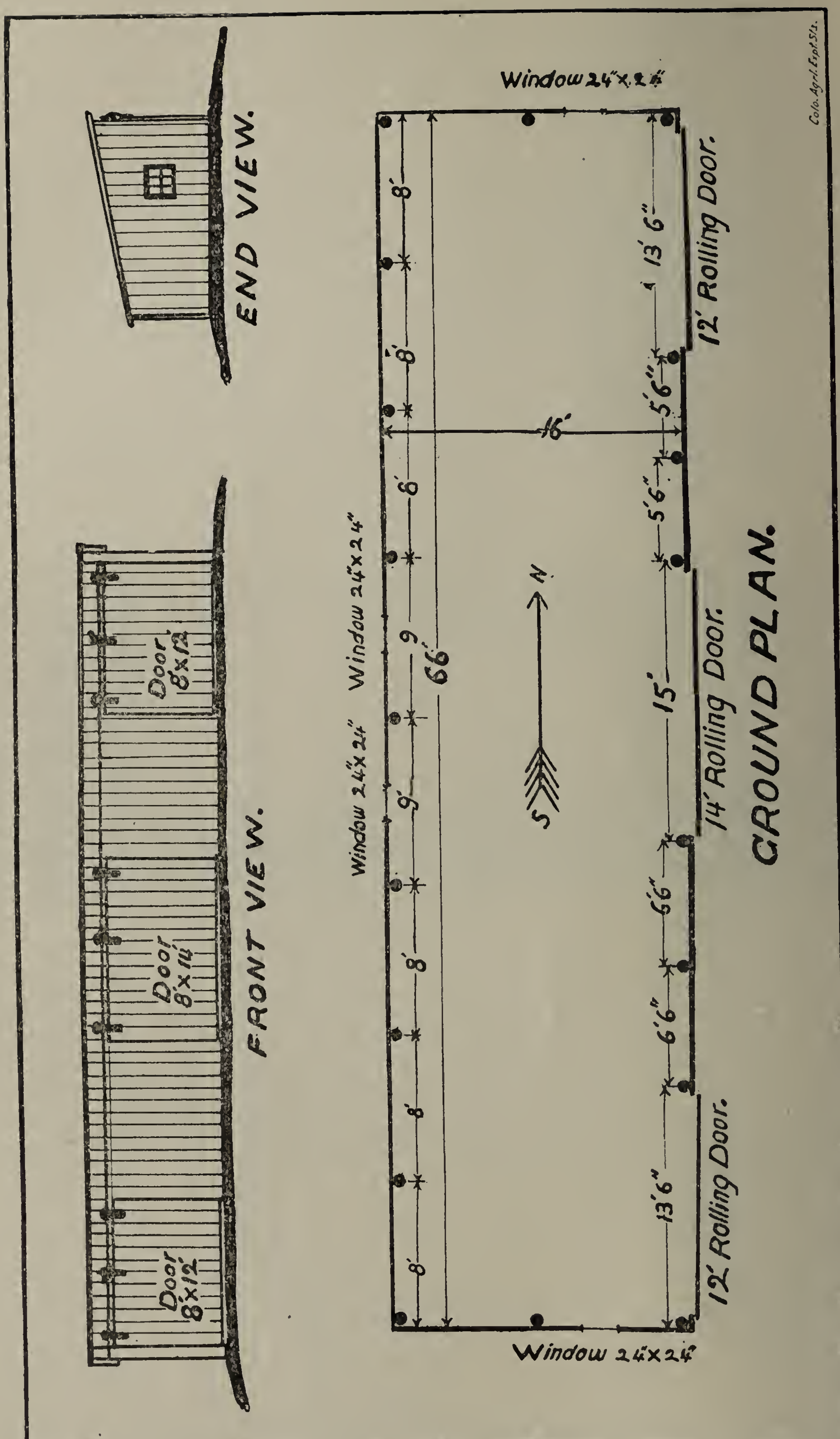

Plate 9. A Very Handy Shed with Corrugated Iron Roof

It becomes necessary to use a 2 in. x 8 in. plate and a 2 in. x 8 in. girt just above the doors to carry the weight of the doors.

The ground upon which the shed sits is about 8 to 12 inches higher than the surrounding ground. This gives a dry earth floor for the machinery.

In the drawing all the doors are closed. In the cut they are opened slightly.

The shed is painted with two coats of white lead in oil.

L. H. Smith

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The Deterioration of Manures Under Semi-Arid Conditions

BY

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AND

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THE DETERIORATION OF MANURES UNDER SEMI-ARID CONDITIONS.

By W. P. Headden and Earl Douglass.

INTRODUCTION.

For many years prior to the introduction of the sugar beet as a commercial crop it was the practice of most Colorado farmers to throw away the manure made upon the farm. The land seemed to be inexhaustibly fertile and work spent in spreading manure upon the land was considered labor wasted. In the early years of our agricultural development, this was, to a certain degree, true. The soil gave bountiful crops year after year, and any additional fertility seemed to do more harm than good by increasing stems and leaves at the expense of grain. During these years the manure, much of it first-class sheep manure from sheep which had been fed upon corn and alfalfa, was dumped into the creek beds or sloughs, or left upon the ground, and the corrals were moved when the layer of manure became so thick that the sheep were likely to jump the fence.

Manure of More Importance than Formerly.

The growing of sugar beets and more intensive methods of farming have changed this, and in those districts in which there are sugar factories, the manure is now carefully saved and spread upon the land. More thought is given to saving the manure and to increasing the supply by fattening cattle or sheep on the farms, the value of the manure being now taken into account as part of the profits. There are still too many places in Colorado where the soil is being robbed, while the means of restoring, or at least partially restoring the fertility is going to waste in neglected manure heaps.

The question of the deterioration of manures under our Colorado conditions is important for the reason that the high freight rates make it impracticable for the western farmer to use the commercial fertilizers which are in common use in sections nearer the great distributing centers, the sea ports and packing houses. In the west, very little attention has been paid either to the subject of fertilizers or barnyard manures and, so far as we know, no analytical data are at hand on the deterioration of manures under semi-arid conditions.

Fresh Manure Should Not be Used on Irrigated Soils.

Another question arises, when discussing the deterioration of manure, namely, the effect of fresh manure upon soils which are sometimes watered scarcely enough to produce a crop. In order to prevent waste of the elements of fertility under humid conditions, the general practice has been to use the manure as fresh as possible.

It probably seems improvident on the part of our farmers to

have left the manure on the farm unused, but this was not wholly due to ignorance or to unwillingness to expend the labor necessary to apply it. The application of fresh manure to irrigated soils involves serious questions which are mentioned in this place merely to explain what must seem to most readers an irrational practice. Many inquiries among practical farmers brought out the fact that there are apparently good reasons for not applying fresh manure, namely, the manure does not rot and produces what is designated as "burning," by which they mean that manured land dries out quickly and the crop suffers. In fact the manure sometimes does more injury than good.

The Samples Studied.

The studies began in 1903 and 1904 during which time all the samples were collected and a large part of the analytical work finished. All the samples came from the vicinity of Fort Collins. Up to this time manures had not been used to any great extent except on small truck farms, lawns and gardens. Many car loads were shipped to Denver and it was a common sight in northern Colorado to see large piles of excellent corn-fed sheep manure left in the waste places of the farm to weather away. While the practice heretofore common among our farmers has been wasteful, the general result was to present an excellent opportunity for the study of the changes which had taken place in the manure due to the exposure to high winds, strong sunshine, and occasional heavy rains. There was no trouble at that time to get sheep or cattle manure of almost any age up to ten years and often even older, one lot being found which was twenty-seven years old. This was not the case with horse manure which, in our dry climate, fire-fangs badly. One instance came under our observation of a pile of horse manure taking fire spontaneously. For this reason practically no horse manure more than a year old can be found and that which has attained the age of a year and has lain in large heaps is simply a mass of dry, blackened stems, having very little value as a manure.

Waste of Liquid Manure.

Where so little attention is paid to the production of manure, no composting is done and the term "manure pile" simply means the pile of manure as it is thrown out of the barn or scraped out of the corrals. It generally contains only such bedding as was put into the stalls or corrals to keep the animals clean and not with the idea of absorbing the liquid manure or using straw as a part of the future fertilizer. No attempt whatever is made to use the liquid manure. If the barn can be so located that the urine runs away into a gutter or sewer, or if

by means of a bed of sand the stall can be kept reasonably dry, the barn is that much better in the estimation of the average Colorado farmer. Even though the cultivation of the sugar beet has caused some improvement in our practice, still too little regard is paid to the saving of the urine, a very valuable, perhaps the most valuable portion of the manure. In the feeding corrals, this is not quite true for much of the urine is absorbed by the solid portion of the manure.

The Older Samples of Sheep Manures.

Some of the older samples came from corrals where sheep or cattle had been fed some previous year but the present owner had followed other pursuits, leaving the corral with its bed of manure untouched. Many of the samples were from piles from four to sixteen feet in height made by scraping out the corrals preparatory to another year's feeding. All the sheep manures, with four exceptions, were from sheep which had been fattened for market and had therefore been fed as much alfalfa as they would eat and a very heavy ration of corn.

Importance in Amount and Value.

The corrals are, in most cases, open pens without shelter except occasionally a board fence to keep off the cold winds. Since the average farmer who fattens lambs, feeds between one and two thousand head for a period of about 100 days, the amount of manure is considerable. In addition, the manure must be more than ordinarily rich in plant food since as much as 95 percent of the potash, phosphoric acid and nitrogen are voided in the dung and urine from sheep on full feed. From the foregoing brief facts it will be seen that we are here dealing with a very rich manure and one which under ordinary conditions would be subject to rapid deterioration.

The Cattle Manure Not so Easy to Obtain.

The cattle manure samples were more difficult to obtain as the industry of fattening cattle had not been so generally practiced. There are, therefore, few samples of manure from corrals where cattle had been fattened, but as this is a growing industry, more and more of it will be produced and its preservation will become correspondingly important.

Sampling.

In case the manure was in the corral, the loose material was scraped off the surface and at least three sections, each about eight inches square, were taken at different places. A portion of the sample was put into a glass vessel and sealed to prevent drying out; the rest was preserved with ordinary precautions.

If the manure was in a pile, an average depth was selected and a hole dug into the pile from the surface to the ground. When a smooth vertical surface was obtained, a slice about eight inches wide and three inches thick was cut from the top to the bottom and placed in a bag. A smaller sample was placed in a fruit jar and sealed. Forty-five of these samples were collected during 1903 and 1904 but no manure pile or corral was sampled unless a fairly accurate history of it could be obtained.

The determinations of free ammonia and moisture were made on the freshly taken and sealed samples. The samples in the bags were air-dried, ground and sampled. Bedding is not used in the corrals unless there is mud, which occurs rather seldom in Colorado. The winter of 1903 and 1904 was particularly open and dry and no bedding was used; for this reason the samples called fresh manure were free from straw, while the older samples were probably nearly so.

Loss of Dry Matter on Weathering.

From the foregoing preliminary remarks, it will be seen that our study will, for the most part, have to do with analyses of manures of different kinds and of various ages gathered at about the same time. There is, however, another factor which must be known before any sharp conclusions regarding deterioration of manures can be drawn, namely, the loss of dry matter through weathering. Any one who has observed a pile of manure in a barnyard knows that it gradually diminishes in bulk and changes its appearance until it is finally difficult to distinguish the manure from the soil itself.

AN EXPERIMENT WITH SHEEP MANURE.

To determine the amount of this loss, ten tons of sheep manure were obtained from a corral where lambs had been finished for market by the usual method. The manure had received no moisture during the whole time of accumulation and was tramped into a hard cake about six inches deep over the whole corral. No bedding had been used although some alfalfa stems from the feeding racks were found in the manure. The ten tons of manure were put into a crib with a board floor on March 2d, 1904, making a heap about 3½ to 4 feet deep. The aeration of the manure in hauling and placing in the crib, caused very active bacterial action which manifested itself in two or three days. To check the heating and settle the manure, it was wet down thoroughly but not enough to cause water to run through the pile.

Ammonia is Lost Rapidly.

A few days after this the smell of escaping ammonia was very

strong, so strong that we tried to measure the ammonia by drawing air from the surface of the pile through normal sulfuric acid. A barrel was fitted with a stop cock in the bottom and used as an aspirator. Several flasks were filled with normal sulfuric acid and connected to a funnel, filled with cotton to prevent particles of manure from finding their way into the flasks. The funnel was simply laid on top of the manure pile and air drawn through the funnel and flasks by means of the barrel aspirator which held about 45 gallons of water or 6.015 cubic feet. When the water had all run out of the barrel, it was found that the flasks contained 0.0885 gram of ammonia.

An open dish of normal sulfuric acid with a surface of 67.2 square inches placed on top of the manure heap, absorbed 0.2606 gram of ammonia in 24 hours. This gives us some idea, vague though it may be, of the enormous loss of free ammonia. This fact has been observed over and over again and many ingenious ways have been used to show it, but each time we are astonished at the magnitude of this loss.

The Manure was Moistened.

Our object in this experiment was not to prevent all loss or even as much of it as is easily possible, but to determine the loss under ordinary conditions. The manure, however, was very dry and to prevent an extraordinary loss, it was thought best to wet it down thoroughly with the hose when first put into the crib. This was the only precaution used to prevent fire-fanging and was used only once.

On June 11, 1904, a hole was dug into the pile to see if any burning had taken place. There were some burned spots but the heavy rains had evidently kept the bacteria partially in check. There was a decided odor of ammonia and the manure was quite moist.

The First Weighing.

It was intended to weigh the manure at the end of the first year, but a long wet spell and work at the laboratory prevented until June 24th, 1905. On turning over the manure at this time, there was no odor of ammonia. The manure was well rotted and quite moist due to the recent rains. There must have been considerable loss from leaching as a rich brown liquid had oozed from the bottom of the crib and had run across the road in several places. A sample of each load was taken and after thoroughly mixing, two samples were drawn, one for the regular analysis and the other placed in a glass can and sealed for a determination of ammonia and moisture. The gross weight at this time was 20,595 pounds.

The Second Weighing.

The next weighing took place on May 18, 1906, and samples were taken as before. There had been heavy rains and the manure was again quite moist. There was no odor of ammonia.

Our Experiment is Stopped.

On March 20, 1907, when the time had come to reweigh the manure, it was found that by mistake a load of this manure had been taken out and used in the greenhouses. Samples were taken for analysis as before but the experiment was of course spoiled. It was hoped this study could be extended over a period of about five years. The results of the experiment are given in Table I.

Loss of Dry Matter as Determined by Other Investigators.

From many experiments conducted by Voelecker, with dung and litter, he concluded that from 30 to 60 percent of the original weight of the manure was lost in the course of six to twelve months time. This would indicate that our manure did not lose as rapidly as do those in climates where there is a heavier rainfall and consequently more leaching taking place. This fact is borne out by a comparison with other experiments as given by Storer in his work on Agriculture, and also by many experiments for short periods of time, generally less than a year. Taking these experiments as a whole, the loss in a year is about 45 to 50 percent, while the loss during this experiment was 32.5 percent in 15½ months, with a rainfall for that time of 26.18 inches, which is much more than the average for this locality.

Character of the Loss in Semi-Arid Climates.

Leaching occurs where the rainfall is heavy and washes away much soluble plant food, but helps to check the loss of ammonium compounds, while a dry climate prevents excessive leaching but destroys much nitrogen by volatilizing the ammonia.

Loss of Nitrogen.

Comparing the determinations of total nitrogen as they stand, without taking into account the loss in gross weight which occurred during the first year, there has been a loss of one-third of the total nitrogen, mostly in the form of free ammonia.

Taking into consideration the loss in weight of dry matter, there is a total or absolute loss of 48.6 percent of the total nitrogen during the first year—surely very startling figures to one who has not calculated the loss for oneself. The remaining manure is, however, more valuable under our conditions than the original larger quantity,

TABLE I.

DETERIORATION EXPERIMENT CALCULATED ON DRY MATTER.

Date	Weight in Pounds	Moisture Percent	Weight of Dry Matter	Loss Percent	Free Ammonia Percent	Total Nitrogen Percent
March 4, 1904	20,000	56.153	8,769	......	1.483	2.713
June 24, 1905	20,595	71.255	5,920	32.487	0.543	2.067
May 18, 1906	12,540	69.743	3,794	56.730	0.187	2.010
March 20, 1907	......	69.697	....	......	0.142	2.310

TABLE I, (Continued).

Date	Potassic Oxid Percent	Phosphoric Acid Percent	Soluble Ash Percent	Insoluble Ash Percent	Total Ash Percent	Sand and Silicic Acid Percent
March 4, 1904	3.892	1.172	6.180	16.756	22.936	8.222
June 24, 1905	5.999	1.004	8.890	22.030	30.920	9.239
May 18, 1906	6.012	1.102	7.468	28.560	36.028	10.678
March 20, 1907	6.189	1.072	7.695	32.040	39.735	12.082

because it can now be incorporated into the soil with advantage, and its humification may be completed in the soil while fresh manure may remain in the ground for years and produce objectionable results.

Loss in Two Years Found to be Less than Wolff Found in One Year.

The second year a further loss of 35.9 percent of dry matter occurred, making a total loss of 56.7 percent of the original dry matter in about two years. There seem to be very few experiments which extend over a period of greater length than one year, and we have consequently none with which to compare this loss. Wolff found that an 80-ton manure heap lost 65.5 percent of its dry matter in one year when exposed to wind and weather. This is much greater than our manure lost in two years. The total nitrogen decreased from 2.713 to 2.30 percent.

Loss of Nitrogen, Potash and Phosphoric Acid.

In order to compare the absolute losses to better advantage the results are calculated to pounds, and the losses given in percent. The original ten tons of manure contained 238.0 pounds of nitrogen, 341.3 pounds of potash and 102.8 pounds of phosphoric acid.

In June, 1905, when the original 8,769 pounds of dry matter had shrunk to 5,920 pounds, there were 122.2 pounds of total nitrogen, 355.1 pounds of potash and 59.44 pounds of phosphoric acid, or a loss of 48.64 percent of the nitrogen, and 42.17 percent of the phosphoric acid. The potash did not lose during the first year.

In May, 1906, the manure had further decreased in weight to 3,794 pounds of dry matter, and there were now present 76.27 pounds of nitrogen, 228.1 pounds of potash, and 41.81 pounds of phosphoric acid. This represents a total loss in two years of 67.95 percent of the nitrogen, 34.69 percent of the potash and 59.32 percent of the phosphoric acid.

In comparison with the losses from our manures, some instances of experiments at other Stations are here given, although it is a difficult matter to compare losses owing to the varying duration of the experiments and methods used.

Some Experiments at the New Jersey Station.

Dr. Voorhees in Bulletin 150 of the New Jersey Station, determined the loss sustained by 100-pound lots of cow manure when exposed to the weather in layers eight inches deep in a special form of galvanized iron box. From four experiments with mixed solid

and liquid manure for an average of 82 days, there was a loss of 51.0 percent of nitrogen, 51.1 percent of phosphoric acid and 61.1 percent of potash. Another experiment by Dr. Voorhees* gives as the results with solid and liquid manure exposed from February 4 to June 15, a period of 131 days, a loss of 57 percent nitrogen, 62 percent phosphoric acid and 72 percent potash.

A Difference in the Losses is Found.

Both of these experiments at the New Jersey Station, while dealing with a different manure under more severe conditions, show very much larger losses in 82 days and 131 days, than our sheep manure exhibited in over one year. This is particularly true of the potash which lost more rapidly than either the nitrogen or phosphoric acid in both the above experiments while, in our experiment with sheep manure, no potash at all was lost during the first year, and only 34.69 percent at the end of the two years. This is certainly a very remarkable fact and shows the very different character of losses in semi-arid climates. With us the heaviest loss is in nitrogen, while the chief loss under humid conditions is potash. This simply indicates the different manner in which the loss takes place. In the humid climate the loss a manure sustains is caused largely by leaching which dissolves the soluble salts, the principal one of which is potash. On the other hand the chief loss in semi-arid climates is nitrogen because it is easily converted into ammonia and lost during dry weather, while the loss of potash is small on account of the smaller number of drenching rains.

A Series of Experiments at the Cornell Station.

Roberts and Wing exposed horse manure loosely piled in a box, surrounded by manure, for a period of six months. The losses were 36.2 percent of the nitrogen, 50.0 percent of the phosphoric acid and 58.8 percent potash. At the same time the foregoing experiment was being tried, a solid block of horse and cow manure, taken as it had been compacted by the trampling of the animals, was exposed to the weather and the losses recorded were 3.2 percent of the nitrogen, 4.7 percent of the phosphoric acid and 35.0 percent of the potash†.

In an experiment the following year a two-ton pile of horse manure lost 60 percent of its nitrogen, 47 percent of its phosphoric acid and 76 percent of the potash. A five-ton pile of cow manure presented an apparent exception to the above three experiments by giving losses amounting to 41 percent of the nitrogen, 19 percent of the phosphoric acid and 8 percent of the potash. Professor Rob-

*New Jersey Report of 1899.

† New York Cornell Station Bulletins Nos. 13 and 27.

erts says of this result, "It is worthy of note that in this experiment the loss of potash was very slight in comparison with the phosphoric acid and nitrogen; in all of our other experiments the heaviest loss has been potash."

Director Peter Collier at the Geneva Station, N. Y. Bul. No. 23, New Series, with a well packed heap of cow manure containing 3,298 pounds, found a loss of 60.6 percent of the potash in one year.

Other experimental proof might be given but in almost every case where the manure is really exposed to the weather and not taken care of, the heaviest loss in a humid climate is the potash.

No comparable experiments with sheep manure were found. The only experiments at our disposal in which sheep manure was used were those of Muntz and Giard as quoted by A. Herbert in an article in the Experiment Station Record. In these experiments the manure was exposed for a period of six months with a loss of 25.04 percent of dry matter, 11.44 percent of nitrogen, 19.15 percent of phosphoric acid and 21.5 percent of potash. It is not clear from the article whether the manure was cared for or not, but one would surmise that it was probably packed in heaps in pits and the leachings pumped back on the pile. If this surmise be true, our conditions are not comparable, and the small losses recorded would be easily accounted for even though the climate of France, where these experiments were conducted, is much more moist than ours.

THE TWENTY-THREE SAMPLES OF SHEEP MANURE.

We will now turn our attention to the samples of sheep manure which were collected during 1903 and 1904. As has already been stated the sheep, or rather lambs, were all fed for eastern markets on corn and alfalfa, with four exceptions, viz. Nos. 31, 32, 34 and 36, in which cases the sheep were pastured during the day and kept in corrals at night, the object being wool rather than the fat lambs. The winter of 1903-04 was an exceptionally favorable one for the collection of samples as there was almost no rainfall during that time and the samples can be compared without allowance being made for leaching.

A Standard Analysis of Sheep Manure.

In order to obtain a standard for comparison, a large number of analyses of sheep manures, most of which are given in Storer's work on Agriculture, were averaged and recalculated to a dry basis as follows:

Average Composition of Sheep Manure.

	Moisture Included Percent	Calculated on Dry Matter Percent
Moisture	66.40	
Dry Matter	33.60	
Ash	7.35	21.875
Potash	0.86	2.559
Phosphoric Acid	0.38	1.131
Total Nitrogen	0.74	2.203

Notes on Table II.

Nos. 14, 15, and 16 were manures made during the winter of 1904 and the sheep had either been shipped or were nearly ready for market.

No. 17 was also made during 1904. This is a sample of the ten-ton lot which was used for the deterioration experiment.

No. 18 lay in the open corral until October, 1903. Smelled strongly of ammonia.

No. 19 lay in an open corral.

No. 20 lay in pile since May 1903.

No. 21 lay in open corral until September, 1903. Pile 3½ feet high.

No. 22 pile three feet high.

No. 23 lay in the corral 1½ years, then was scraped into a pile 8 feet high. Inside of pile quite warm but did not seem to be fire-fanged.

No. 24 pile 3 feet high.

No. 25 pile 3½ feet high.

Nos. 26 and 27 from different farms. Piles four feet high. In piles two years.

No. 28 pile 2½ feet high.

No. 29 two years in pile.

No. 30 pile 2½ feet high. Had been dumped near slough.

No. 31 sheep pastured on range during the day. Lay in an open corral.

No. 32 same as above except that it was under cover of a shed.

No. 33 had been put on top of other manure, but took only that which was four years old. Pile 5 feet high.

No. 34 pile 3½ feet high from same place as No. 31.

No. 35 had been hauled from the corral and dumped in a low, rather wet place.

No. 36 from a corral which had been used to shelter sheep which were pastured on the range. Manure about eight inches deep. Scraped off loose material before taking sample.

TABLE II.

PERCENTAGE COMPOSITION OF SHEEP MANURE, CALCULATED ON AIR-DRIED MANURE.

No.	Age Years	Moisture	Dry Matter	Soluble Ash	Insol. Ash	Total Ash	Sand and SiO_2	Potash	Phosphoric Acid	Crude Fiber	Free Ammonia	Total Nitrogen Fresh Sample	Total Nitrogen Air-dried Sample
14	Fresh	61.748	38.252	7.454	11.878	19.332	3.666	4.975	1.145	35.310	1.757	3.107	1.797
15	Fresh	59.638	40.362	10.218	14.892	25.110	5.828	3.594	1.211	33.370	1.724	2.894	1.745
16	Fresh	55.642	44.358	8.012	18.586	26.598	11.160	5.200	0.812	31.180	1.888	3.011	1.854
17	Fresh	56.153	43.847	6.180	16.756	22.936	8.222	3.892	1.172	33.805	1.483	2.709	1.847
18	1	54.873	45.127	7.352	36.544	43.896	28.134	5.617	1.299	27.440	1.680	1.935	1.430
19	1	63.573	36.427	9.744	12.942	22.686	5.051	6.919	1.157	40.010	1.715	2.385	1.331
20	1	50.047	49.953	8.762	32.294	41.056	23.582	7.873	1.104	36.525	0.156	1.831	1.673
21	1	47.923	52.077	7.217	38.743	45.966	25.220	4.858	1.010	27.760	0.437	1.715	1.529
22	2	58.735	41.265	7.377	49.231	56.608	35.510	2,522	1.784	16.780	0.080	1.865	1.552
23	2	55.478	44.522	8.217	34.052	42.269	22.980	6.218	1.118	23.280	0.546	1.698	1.400
24	2	58.680	41.320	7.998	38.798	46.796	10.420	8.987	1.052	30.065	0.499	1.657	1.405
25	3	61.623	38.377	8.586	29.822	38.408	19.723	6.149	1.419	29.530	0.886	2.110	1.465
26	3	52.613	47.387	8.734	43.202	51.936	32.106	5.622	0.841	20.545	0.509	1.542	1.672
27	3	58.302	41.698	7.080	58.210	65.290	17.828	4.862	1.197	6.890	0.017	1.511	1.633
28	3	48.180	51.820	5.916	57.005	62.921	44.331	5.332	1.112	12.265	0.073	1.556	1.410
29	3	53.527	46.473	7.084	40.964	48.048	28.159	5.525	1.224	24.485	0.138	1.679	1.586
30	4	65.958	34.042	8.969	33.926	42.895	18.969	1.854	0.760	27.045	0.444	1.559	1.637
31	4	40.629	59.371	5.964	49.418	55.382	36.622	5.172	0.710	9.480	0.047	1.592	1.533
32	4	24.239	75.761	7.220	45.196	52.416	32.990	3.543	0.687	16.560	0.156	1.524	1.552
33	4	62.817	37.183	13.638	25.822	39.460	15.270	7.371	1.360	26.300	0.212	2.157	2.262?
34	5	32.543	67.456	4.512	71.240	75.752	56.802	3.974	0.689	3.205	0.022	1.179	1.217
35	5-6	64.304	35.696	5.832	40.418	46.250	24.679	6.317	1.833	22.920	0.759	1.786	1.678
36	27	34.426	65.574	5.526	64.382	69.658	37.250	3.843	0.718	4.565	0.028	1.185	1.152

Influence of Feed upon the Value of Manure.

Since the feed has a great deal to do with the amount of plant fertility in the manure, this should be taken into consideration when discussing different manures. Most of the manures used in the standard analysis were from sheep fed on hays, beets, pasture and a few on alfalfa, but almost none were from feeding pens where sheep had been fattened and had received as much as they would eat of corn and alfalfa. The alfalfa being very rich in nitrogen of course produces a manure rich in that element also. The difference in feed is forcibly illustrated in Table II. The potash, phosphoric acid and nitrogen drop decidedly in Nos. 31, 32, 34, and 36, which are from sheep pastured on native grasses. No. 30 is also low in these constituents, but for another reason. It had been dumped into a slough and had every chance to leach out. The sample was taken with the idea that it was as badly taken care of as any which came under observation.

Our Manures Lack Moisture.

The most noticeable difference between the standard analysis and the analyses as given in Table II is the low percentage of moisture. Not one is as high as the average analysis, and but few approach it. The average of the moisture determinations given in Table II is 53.115 percent which is 13.285 percent below that of the average analysis. These figures bring prominently before us the fact that our manures are comparatively very dry.

Soluble Ash.

In dividing the ash into soluble and insoluble ash, it was thought that an increase in the soluble portion would be found as the manure increased in age. We know that the insoluble organic matter is being constantly changed in form and much of it rendered soluble, but from a consideration of Table II, one is forced to the conclusion that the soluble ash is rather a constant quantity, not varying much from the average, 7.7 percent, except in a few instances. In the deterioration experiment we had for the soluble ash:

Fresh Manure	6.180 percent
First year	8.890 percent
Second year	7.468 percent
Third year	7.695 percent

These results are also very close together and seem to show that the manure can hold about 7 percent soluble matter, the rest being leached out.

Results for Potash Differ from those in Humid Climates.

In discussing the potash in the ten-ton lot of sheep manure, it was pointed out that there was no loss of potash during the first year although the manure lost 32 percent in weight in that time. The determinations given in Table II corroborate the fact that the potash accumulated during the first year and are repeated below in order that this fact may be clearly seen.

Percent of Potash in Fresh Manures	Percent of Potash in One-Year-Old Manures
4.98	5.62
3.59	6.92
5.20	7.87
3.89	4.86
Average 4.42	Average 6.32

The results of the deterioration experiment were 3.89 percent in the fresh and 6.00 percent in the one-year-old samples.

After the first year the potash does not seem to accumulate further, and taking into consideration the loss in weight which occurs each year, there is an absolute loss from that time on.

Phosphoric Acid.

The phosphoric acid determinations are very close together varying very little from 1.2 percent with a few exceptions due for the most part to a difference in feed.

An interesting question arises as to the loss of phosphoric acid and the accumulation of potash during the first year. From what we know of the phosphates, they are as soluble as the potash salts and the loss of phosphoric acid can therefore hardly be accounted for by the leaching which took place.

Crude Fiber.

The crude fiber is a determination not often made on samples of manure, and does not appear to be of much value here as a criterion of either the age or the value of the manure. In a general way, the crude fiber decreases with age, but there is a wide range in the figures without any apparent reason for it.

Nitrates.

The question of nitrates in the manure did not come up until most of the samples had been thrown away. However, the results obtained

are of considerable interest as some of the samples gave abnormal amounts of nitrogen as nitrates. The following table gives the results obtained from those samples which had been kept.

Sample No.	Age	Percent N_2O_5
17	Fresh	None
17	1¼ years	0.465
17	3 years	0.752
15	Fresh	None
16	Fresh	Trace
18	1 year	0.371
21	1 year	0.108
25	3 years	0.287
26	3 years	1.610
27	3 years	0.821
31	4 years	0.188
33	4 years	2.151
35	5-0 years	0.093

The method used for these determinations was that of Schlosing and Grandeau as modified by Tieman and Schulze. Ten to twenty grams of manure were extracted with water and the filtrate and washings concentrated to a convenient volume from which point the above method, depending upon the reduction of nitric acid to nitrous oxid, was used. Precaution was taken in each case to absorb all carbonic acid by means of solid caustic soda in contact with the gas. To make sure that the gas was really NO, oxygen was admitted to the measuring tube a bubble at a time, and it was then found that all the gas oxidized readily and dissolved in water.

Voelecker* found only traces, not enough to determine quantitatively, of nitrates in either fresh or rotted manures. Holdefeiss also says that no nitrates are found when the manure is kept moist but that nitrates can form if the manure is covered with earth or is allowed to dry out. Holdefeiss found that as high as 8.5 percent of the nitrogen was present in a moist heap covered with earth, and an unmoistened heap carried as much as 18 percent of the nitrogen as nitrates.

The manure piles considered in this bulletin were, of course, not covered with earth and were not moistened except by the infrequent rains. The fresh manure contained none or doubtful traces of nitrates. In manure No. 17 there has been a steady increase in nitrogen as nitrates from none in the fresh manure to 8.5 percent of the nitrogen present as nitrates in the three-year-old manure. The other samples do not follow this increase with age, some being high and some very low in nitrates. Nor does the amount of nitrate present seem to be governed

*As given in Storer's Agriculture Vol. II. p. 319.

by the amount of moisture in the manure. The probability is that the conditions were right in some manures for the work of nitrifying bacteria. In other manures the nitrates had been washed away or nitrification had not taken place.

The three highest results, viz., Nos. 26, 27, and 33, have 27.13, 14.13 and 25.94 percent, respectively, of their nitrogen present as nitrates, which will be seen to be abnormally high as compared with Holdefeiss' figures.

The question might be raised whether nitrification had not proceeded in the sample cans in the laboratory. This was effectually settled in the case of No. 17. A determination of the nitrates in the three-year-old sample had been made in 1906 and a re-determination of nitrates in 1910 gave practically the same result. Air-drying the manure seems to stop most bacterial changes.

THE FREE AMMONIA.

The free ammonia in the manures which have been discussed in the foregoing pages offers a very interesting study not only because of the larger amount in fresh manures, but because it is the most easily lost of all the elements of fertility under our conditions. It has been pointed out that the principal loss from manures under humid conditions is potash but that the greatest loss in our climate is nitrogen. From the following discussion it will be seen that this loss occurs principally through a loss of free ammonia.

The bacterial changes taking place in the manure heap are very complex and not fully understood, but it is certain that among the first of these changes is the ammoniacal fermentation which first changes the nitrogen compounds of the liquid manure into ammonium salts, or allows the ammonia to escape into the air. Some of the ammonium salts are now oxidized to nitrites but are not changed into nitrates until all the ammonia has been dissipated or has combined to form neutral salts. The process is quickly completed in the liquid manure which contains organic nitrogen in a soluble form. The nitrogen in the solid portion is also attacked by ammonifying bacteria, but this change takes place slowly, which allows more time for the change into nitrates and nitrites. The great loss of ammonia from our sheep manures, however, must come from the comparatively swift change of large amounts of hippuric acid from the liquid manure into ammonia through the agency of uro-bacteria.

We know that most of this ammonia immediately combines to form ammonium carbonate, and being in this form it is peculiarly susceptible to changes in temperature and to the presence or absence of moisture. Now ammoniacal fermentation takes place most readily when the bacteria have a plentiful supply of air, warm sunshiny weath-

er, and comparatively dry manure. It is easy to see, therefore, why manures under our conditions lose so much of their nitrogen. The bright, almost continuous sunshine and drying winds, are the two greatest agents tending to dissipate this valuable element of fertility. Another factor which is responsible for great loss of ammonia is the way in which our manures are cared for, viz., the practice of scraping the manure out of the corral into a loose pile. Admitting the air into the manure heap in this way both dries it out and supplies a plentiful amount of oxygen which gives just the right conditions for intense aerobic activity, especially when the cleaning of the corrals takes place in the summer time, as is usually the case. If the manure was compacted and moistened thoroughly, or put into pits and the leachings pumped back on the pile, as is the custom in France, the loss would be negligible in comparison with the good done by the slower and less destructive anaerobic fermentation.

What has just been stated regarding the loss of ammonia from manure which has been loosely piled up is well illustrated by four samples from Table II, viz., Nos. 18, 19, 20, and 21. These manures are all one year old, but had been treated in different ways by the farmers who owned them. Number 18 was scraped into a pile the fore part of November, a few days before the sample was taken. Number 19 lay untouched in an open corral. Number 20 had been scraped into a pile in May, and Number 21 early in September. Samples of these manures were collected in November and analyzed immediately with the following results:

No. 18 ....1.68 percent free ammonia.
No. 19 ....1.72 percent free ammonia.
No. 20 ....0.17 percent free ammonia.
No. 21 ....0.44 percent free ammonia.

While they are of the same age, we see that Nos. 20 and 21, which had been scraped into piles, had lost almost the whole of their free ammonia. Number 18, which had been placed in a pile a little while before the sample was taken, smelled very strongly of ammonia and was therefore losing ammonia rapidly at that time and probably dropped from 1.68 percent in the course of two or three months down to the level to which Nos. 20 and 21 had fallen in a like time. Turning now to No. 19, which lay in an open corral compacted by the trampling of the sheep during the feeding time, we find 1.72 percent, the same amount of free ammonia found in the fresh manures. The lack of air practically stopped the action of aerobic bacteria and anaerobic fermentation had proceeded slowly within the layer of manure.

An objection might be raised that the difference in content of free ammonia was the result of unequal bacterial activity, and that more ammonia had been formed in No. 19 than in the others, but a comparison of the determinations of total nitrogen in the thoroughly dried samples, shows that the ammonia had been formed in equal amounts in these manures, but had been lost before being changed into a form which could be better retained by the manure.

This can be seen to better advantage by repeating the figures given in Table II for these four manures.

	Total nitrogen in fresh samples.	Total nitrogen in air-dried manure.
No. 18	1.935	1.430
No. 19	2.385	1.331
No. 20	1.831	1.673
No. 21	1.715	1.529

It will be noticed that all four manures have nearly the same amount of nitrogen in the air-dried samples, and since the sheep were all fed alike, at the same time and in the same way, it would be reasonable to suppose that these manures had over two percent of total nitrogen as they lay in the corrals and it was only when they were scraped out and aerated that the ammonia was lost.

Another factor tending to preserve the ammonia in No. 19 was the larger amount of water present.

No. 18	54.87	percent moisture.
No. 19	63.57	percent moisture.
No. 20	50.05	percent moisture.
No. 21	47.92	percent moisture.

No. 19 had not lost its moisture because it had been left undisturbed in the corral, and this was not due to a favorable location. The corral in which it was found was on top of a hill with no shade of any kind. No. 18 probably had just as much or more moisture as it lay in the corral a few days before, but in scraping it up and hauling to the pile it had lost about 9 percent as we are justified in concluding from the fact that comparable samples from the same farm contained 62 and 63 percent moisture.

Table II shows how dependent the percentage of free ammonia, and to a slighter degree that of the total nitrogen, is upon the water content of the manure. The more moisture in the manure the more free ammonia and total nitrogen is present. There are three samples, Numbers 18, 25, and 33 which came from the same farm. They were on the north side of a row of thickly set cottonwoods and the moist condition was noticeable at the time of taking the samples. Their larger percentages of total nitrogen, 1.935, 2.110, 2.157, show the

fects of the larger content of moisture which prevented a part of the ss of ammonia, or, which amounts to the same thing so far as the ilue of the manure is concerned, retarded ammonification, and allow- l more time for the formation of ammonium salts. The moisture so helps check excessive heating, which dissipates much of the nitro- n as ammonia in a semi-arid climate.

Another prominent case in point is No. 35, with 64 percent oisture which, though five or six years old, has retained 0.759 per- nt free ammonia.

It will be noticed that the free ammonia amounts to about half e total nitrogen in the fresh manures and that there was a large loss ı air-drying these samples. As we pass down the table to the older anures, this loss on drying becomes less until from No. 30 on there scarcely any free ammonia, and practically no loss on air-drying, ex- pt in the case of No. 35 which was moist enough to retain 0.759 per- nt of free ammonia. This seems to indicate that at the end of about ree years ammonification has entirely ceased, and the ammonium salts rmed have either been lost or changed into nitrites and nitrates. It is obable that ammonification practically ceases long before this, es- cially when the manure has been disturbed and aerated.

The Loss of Ammonia in the Deterioration Experiment.

The "fresh" manure, or the manure as it was taken out of the rral, contained 1.48 percent of free ammonia, which makes 130 unds in the ten tons of manure. At the end of 15 months there were t 32.2 pounds of ammonia. If no loss had occurred during this ne our total nitrogen ought to be about the same in the sample ıen placed in the crib and again a year and a quarter afterwards, but : find that the total nitrogen has shrunken from 237.9 pounds in the ı tons to 122.4 pounds when sampled again, a loss of 115.5 pounds. e know that some leaching occurred during this time but it surely ıld not have been of much consequence when no potash was lost. ıe loss of nitrogen must, therefore, occur almost wholly through a s of ammonia.

Furthermore, from a series of determinations of nitrates, as given ewhere in this bulletin, there was present but 0.121 percent of the nure as nitrates at the end of 15 months. There might have been ne nitrates present, but certainly not much of the ammonia had en converted into nitrates.

In all probability the greater portion of the work of ammonifica- n had taken place and the 32 pounds of free ammonia obtained at e end of 15 months were simply ammonium salts awaiting nitri- ation. At the end of the second year there were but 7.1 pounds

of ammonia, showing that ammonification had now almost entirely ceased, if, indeed, it had not done so sometime previously.

The further loss of 46.1 pounds of total nitrogen during the second year points to the fact that ammonia was still escaping, though much less rapidly than in the fresh manure.

Another fact responsible at times for large losses of nitrogen is the presence of denitrifying bacteria which set free elementary nitrogen.

CARBON AND HYDROGEN.

Elementary carbon and hydrogen determinations were also made on these samples of manure, the object being to find out to what extent the carbon accumulated in the manure as it grew older. Theoretically it would seem as though the amount of carbon would increase as the manure is changed by the bacteria with the formation of soluble salts and setting free of gases. Since the insoluble ash accumulates with the age of the manure, this factor must be eliminated in the results. The percentages of carbon and hydrogen are, therefore, re-calculated which gives a better basis for comparison.

The re-calculated results present a remarkable series. Far from being a variable quantity or showing any accumulation with age, the ratio of the carbon to the hydrogen is as constant a quantity as if the material were a series of lignite coal samples rather than manures. The average gives a ratio of 33.6 to 4.9. The breaking down of the cellulose with the liberation of carbon dioxide has kept pace with other kinds of fermentation leaving the same relative amounts of both carbon and hydrogen present in the manure.

TABLE III.

Carbon and Hydrogen in Sheep Manures.

The results are in percent of air-dried manure.

Sand and Silicic Acid Included				Sand and Silicic Acid Excluded	
No.	Age	Carbon	Hydrogen	Carbon	Hydrogen
14	Fresh	37.809	5.682	39.250	5.843
15	Fresh	33.110	5.021	35.160	5.332
16	Fresh	30.095	4.808	33.875	5.412
17	Fresh	29.011	4.803	31.610	5.331
18	1 year	24.712	3.649	34.385	5.078
19	1 year	34.521	5.276	36.358	5.557
20	1 year	25.130	3.575	32.884	4.678
21	1 year	25.695	3.668	34.722	4.905
22	2 years	23.623	3.110	36.630	4.823
23	2 years	27.291	3.792	35.434	4.924
24	2 years	25.942	3.560	28.950	3.974
25	3 years	28.686	4.069	35.734	5.069
26	3 years	22.580	3.092	33.258	4.554
28	3 years	16.910	2.276	30.376	4.089
29	3 years	25.398	3.443	35.344	4 792
30	4 years	28.680	3.776	35.394	4.660
31	4 years	22.450	3.195	35.423	5.041
32	4 years	25.215	3.483	37.630	5.198
33	4 years	27.624	3.968	32.602	4.683
34	5 years	12.600	1.609	29.169	3.725
35	5-6 yrs	25.471	3.590	33.816	4.766
36	27 years	12.748?	2.717	20.317?	4.431

THE CATTLE MANURES.

We will now turn our attention to the cow or cattle manures collected during the same winter as the sheep manures, but not presenting so continuous a series. To enable a better comparison, we give an average analysis which is obtained from about fifty analyses as given by Storer in his "Agriculture." Many of the analyses included in this average are of fresh manures, but this does not affect the results for they were not much higher in moisture than the old manures. This average represents manures as they are met with in moist climates.

Average Composition of Cow Manure in Percent.

	Moisture Included	Dry Matter Only
Moisture	74.66	
Dry Matter	25.34	
Ash	4.31	17.01
Potash	0.56	2.21
Phosphoric Acid	0.32	1.26
Total Nitrogen	0.57	2.24

TABLE IV.

PERCENTAGE COMPOSITION OF COW MANURES, CALCULATED ON AIR-DRIED MANURE.

No.	Age Yrs.	Moisture	Dry Matter	Soluble Ash	Insol. Ash	Total Ash	Sand and SiO_2	Potash	Phosphoric Acid	Crude Fiber	Free Ammonia	Total Nitrogen Fresh Sample	Total Nitrogen Air-dried Sample
1	1	31.534	68.466	5.275	54.315	59.590	41.885	5.151	0.629	18.235	0.229	0.914	1.080
2	2	69.230	30.770	5.595	47.597	53.192	36.988	3.647	0.727	20.445	0.397	1.624	1.101
3	3	39.109	60.891	4.612	60.616	65.228	48.285	3.965	0.660	15.840	0.035	0.558	1.005
4	10	66.081	33.919	7.676	39.208	46.884	25.977	6.899	1.482	24.375	0.316	1.661	1.665
5	10-12	49.110	50.890	3.189	58.133	61.322	43.865	3.511	0.808	16.075	0.022	1.147	1.135
6	3	65.732	34.268	9.992	37.814	47.806	22.954	6.665	0.939	22.575	0.665	1.825	1.484
7	½	38.490	61.510	2.300	39.946	42.246	32.553	2.599	0.702	18.480	0.057	1.415	1.424
8	½	54.328	45.672	7.966	32.188	40.154	28.494	4.022	0.839	14.550	0.261	2.220	1.851
9	1	76.112	23.888	5.469	35.654	41.123	27.743	4.030	0.776	24.300	0.092	1.740	1.538
10	2	57.380	42.620	4.434	48.024	52.458	39.500	3.639	0.958	4.325	0.141	1.523	1.369
11	2-5	44.218	55.782	2.552	52.776	55.328	44.600	5.588	0.794	7.995	0.023	1.606	1.542
12	10	48.736	51.264	3.730	56.830	60.560	45.160	5.201	0.984	7.500	0.084	1.405	1.347
13	18	35.978	64.022	.....	......	72.344	64.651	5.396	0.687	2.685	0.015	0.941	1.014

Notes on Table IV.

o. 1. This manure was in a pile five feet high. The cattle were fed alfalfa hay.

o. 2. Manure was in corral one year and was then put in pile four feet high. The feed was alfalfa hay.

o. 3. This manure still lay on the ground in the corral. The feed was alfalfa hay.

o. 4. This manure was in a pile four feet high. The feed was alfalfa hay and corn.

o. 5. Only a small amount of this manure remained. The feed was corn, barley and alfalfa.

o. 6. This manure was in a pile four feet high. The feed was corn and alfalfa.

o. 7. This manure was from milk cows, pastured during the day on native mountain grasses. No grain fed.

o. 8. From milk cows fed as No. 7.

o. 9. This manure was in pile three and one-half feet high. The feed was alfalfa and timothy hays.

o. 10. This manure was made under cover of a shed, and had not been piled up. The feed was native, timothy and alfalfa hays.

o. 11. Same as above except that only native hay was used.

o. 12. This manure was undisturbed in a corral for two years and was then placed in a pile and remained there for eight years. The feed was native hay.

o. 13. This manure was from a pile which had weathered until it was but one and one-half feet high. The feed was native hay.

Moisture is Low in Cattle Manures.

A comparison of Table IV with the average analysis given shows most striking difference in the moisture content, nor is this difference ue to the inclusion of a number of fresh manure analyses in the stanard analysis, for in an experiment conducted by the New York tation, Geneva Bul. No. 23, New Series, the moisture in the manure fter one year's weathering is given as 75.18 percent. The average mount of water in the 13 manures given in Table IV is 52 percent r 22 percent less than in the average analysis. The cow manures re drier even than the sheep manures which had 13.3 percent less noisture than the standard analysis. Number 9, which has 76 percent noisture was from a pile under the eaves of a barn where it received he water from the roof during rainstorms.

There Was Some Difficulty With Sand.

The total ash is high compared with the average, but when th sand and silicic acid are subtracted, the results are very close to thos of the standard analysis. One of the difficulties with a few of th older samples of the cow manures was the presence of large amoun of sand and gravel which had been blown or trampled into them. Li erally a quart or two of gravel had to be picked out of some of th samples before anything in an analytical way could be done with then For this reason the sand and silicic acid were carefully determined i the ash, although some of the silicic acid belongs to the ash of th manure as it was a constituent of the plants the animals fed upon.

The Soluble Portion is Nearly a Constant Quantity.

While discussing the soluble and insoluble ash in sheep manure, was stated that the soluble ash did not increase with age, but remaine near 7 percent. This is also the case with the cow manures, excep that the soluble ash amounts to about 5 percent. This probably poin to the fact that the manure can retain about that amount of soluble asl the rest being lost through leaching. We know from many exper ments, some of which have already been cited in connection with th discussion of sheep manure, that all manures lose rapidly in bulk an weight when exposed to the weather, and an increase in the ash con tent, soluble as well as insoluble, should take place, but we find th the soluble ash remains constant. The loss consists chiefly of solub salts and liberated gases, such as carbon dioxide and nitrogen, cause by the action of micro-organisms. From the results given in Table I it would seem that almost the whole of these soluble salts are lo since the manure retains only about 5 percent no matter how old it i This loss is principally due to leaching, for some of our rainfalls a heavy, and sometimes extend over a considerable period.

Solubility of the Nitrogen, Potash and Phosphoric Acid in Water.

It was so unusual to find the potash retained by the manure to greater extent than the nitrogen, that 200 grams of manure No. 1 were extracted with water, and the potash and phosphoric acid de termined in the extract.

After washing with water there remained 164.4 grams of manu making a loss in the extract of 17.8 percent. The nitrogen was de termined in the residue and in the original sample, the former givin 1.817 percent and the latter 1.125 percent, a difference of 0.692 pe cent, which was the amount soluble in water. The phosphor acid in the soluble portion amounted to 0.265 percent and the potas to 1.700 percent calculated on the air-dry manure. This shows co clusively that it was not because the potash was held as some insolub

salt in the manure but because there had not been enough rain to wash out the potash during the first year. The above figures represent a loss of 43.7 percent of the potash, 22.6 percent of the phosphoric acid and 38.0 percent of the nitrogen, which correspond closely to the results obtained under humid conditions.

Potash and Phosphoric Acid.

Since the potash salts and the phosphates are among the soluble salts, we find they are among those lost by leaching. It was pointed out that the phosphoric acid in the sheep manure was lost at about the same rate that leaching occurred. This seems to be the case here as the phosphoric acid determinations run very close together with the exception of No. 4, which is probably high on account of the heavy ration of corn and alfalfa these cattle received. The potash determinations vary to a greater extent than those of the phosphoric acid, but to what this is due is a question. The cattle manures are much more unsatisfactory than the sheep manures, because so many different combinations of hays and grains fed are represented. The rich feed gives a manure rich in plant food, and this difference sometimes persists after years of weathering. The phosphoric acid and nitrogen are less than results given in the standard analysis, while the potash is much higher. This again emphasizes what has been said regarding the loss of potash from sheep manure, and corroborates the statement that the heaviest loss under our conditions is not potash but nitrogen. The average of 13 potash determinations is 4.64 percent, more than twice the percentage in the standard analysis.

There is, of course, an absolute loss of potash as the manure loses in weight through weathering. This loss probably begins at about the same time it did in the sheep manure, namely, after the first year, and from that time on, like the phosphoric acid, it is lost at about the same rate as the manure loses in weight.

The Nitrogen.

The total nitrogen is lower than in the standard analysis. The average of Table IV is 1.43 percent, while the standard analysis gives 2.24 percent. The standard analysis is composed of very much younger manures than those in Table No. IV, and it will be noticed that the only manure in the table, No. 8, having an amount of total nitrogen equal to the standard analysis, is but six months old. Since the total nitrogen is low compared with the standard analysis, the absolute loss must be very large. The loss of nitrogen on air-drying the samples follows closely the results as given under the sheep manures, i. e., the loss is heaviest where there is the most free ammonia. There are some results in which an apparent gain is

made on air-drying. The cow manures were much harder to sample than the sheep manures, and this probably accounts for some discrepancies in the results.

TABLE V.

Carbon and Hydrogen in Cow Manures.

The results are in percent of air-dried manure.

Sand and Silicic Acid Included				Sand and Silicic Acid Excluded	
No.	Age in years	Carbon	Hydrogen	Carbon	Hydrogen
1	1	20.450	2.690	35.188	4.630
2	2	23.920	3.193	37.961	5.067
3	3	18.480	2.418	35.735	4.676
4	10	23.564	3.388	31.833	4.577
5	10-12	6.884?	2.698	12.263?	4.806
6	3	25.414	3.256	32.982	4.226
7	½	24.871	4.029	36.876	5.974
8	½	27.092	4.313	37.887	6.032
9	1	28.412	4.001	39.321	5.537
10	2	20.784	3.208	34.354	5.302
11	2-5	19.983	2.859	36.071	5.161
12	10	18.946	2.739	34.546	4.995
13	18	12.266	1.366	34.771	3.863

Table V, like Table III, gives a series of carbon and hydrogen determinations which are remarkably close together. The average of the carbon determinations with sand and silicic acid calculated out is 33.8 percent and the hydrogen is almost an even 5 percent. Now the ratio of the carbon to the hydrogen in the sheep manures was 33.6 to 4.9 which are about the identical figures for the cow manures. There is then practically a constant amount of carbon and hydrogen in both sheep and cattle manures.

Some Miscellaneous Manures.

Table VI contains those manures which were not all of one kind, but are rather to be classed as mixed stable manures. Two of the manures, Nos. 44 and 45, are horse manure alone.

TABLE VI.

PERCENTAGE COMPOSITION OF MISCELLANEOUS MANURES, CALCULATED ON AIR-DRIED MANURE.

No.	Age Yrs.	Moisture	Dry Matter	Soluble Ash	Insol. Ash	Total Ash	Sand and SiO_2	Potash	Phosphoric Acid	Crude Fiber	Free Ammonia	Total Nitrogen Fresh Sample	Total Nitrogen Air-dried Sample
37	2	64.224	35.776	7.344	38.500	45.844	27.260	6.106	1.175	26.825	0.808	2.024	1.373
38	6	50.749	49.251	3.507	68.763	72.270	57.190	6.140	0.684	11.555	0.181	1.204	0.832
39	4-5	55.623	44.376	6.184	42.005	48.189	25.820	3.622	0.976	23.155	0.095	1.387	1.499
40	10	58.897	41.103	6.007	42.661	48.668	26.271	3.302	0.972	26.575	0.136	1.661	1.485
41	20	57.402	42.598	2.746	58.935	61.681	45.800	6.203	1.353	7.720	0.035	1.908	1.313
42	3	52.115	47.885	2.327	55.049	57.376	45.730	5.106	1.055	7.250	0.027	1.520	1.417
43	6	40.344	59.656	0.910	68.102	69.012	59.741	2.214	0.560	2.360	0.020	1.149	1.104
44	Fresh	64.304	35.696	5.832	40.418	46.250	18.633	8.196	0.994	28.235	1.198	2.057	1.277
45	1¼	34.909	65.090	6.698	45.688	52.386	32.420	5.147	1.002	19.485	0.143	1.299	1.507

Notes on Table VI.

No. 37. Sheep and cattle. Pile 8 feet high. Very moist.
No. 38. Sheep and cattle. Pile 8 feet high.
No. 39. Sheep and cattle. In open corral undisturbed.
No. 40. Sheep and cattle. In open corral undisturbed.
No. 41. Horse, hog and cattle. In pile at least 15 years.
No. 42. Cattle and horse.
No. 43. Mixed stable manure. Considerable hay and dirt in the manure.
No. 44. Horse manure, made by work horses. Fed heavily on barley, bran, corn and alfalfa.
No. 45. Horse manure. Pile 6 feet high. Not much bedding used. Interior badly fire-fanged.

It will be noticed that the potash is high, and that the phosphoric acid runs about 1 percent. The moistures in the two horse manures are interesting in showing how this kind of manure practically burns up. At the end of 1 1-4 years there was only 35 percent moisture, and the whole interior of the pile was a mass of dry stems, so badly was it fire-fanged. It is rather surprising, however, to see how much nitrogen remained in the burned manure, although by far the greater portion of it had been lost.

Preservation of Manure.

Knowing at about what rate the manure deteriorates, and what elements of plant food are most easily lost, a few hints might not be out of place as to some waste which can be stopped by good management. Since the nitrogen, particularly as free ammonia, is the most easily lost in a dry climate, that is the substance we must preserve.

We have seen that piling up manure loosely causes intense bacterial action, and consequently loss of free ammonia. It will be best, therefore, to leave the manure in the corral until it can be hauled out and spread on the ground. If the corral must be cleaned, pile the manure in a shady place where its moisture will be retained. If at all possible and the weather is dry, moisten the manure with the hose after it has been placed in the pile; or, lacking any way of moistening the manure, try to clean the corral during wet weather.

Any method of compacting the manure pile to keep out the air will be found to help largely in conserving the nitrogen.

If both cattle and horse manure are produced on the farm, probably much of the horse manure could be rotted and yet not badly fire-fanged by mixing the two manures. Here, too, an occasional wetting would save much fertility.

Fresh sheep manure particularly should not be spread upon the l under our conditions, but rotting about six months, or at .t a year, is all that is necessary to put the manure in fine condition immediate assimilation by plants.

Recapitulation.

The main facts brought out by the deterioration experiment are ollows:

Manure under our conditions does not lose in weight as rapidly as nore humid regions. The sheep manure lost 32.5 percent in weight bout 15 months, and 56.7 percent in a little over two years.

About half (48.6 percent) of the total nitrogen was lost during first 15 months, and 68 percent was lost in two years. The total ogen sustains the heaviest loss of any of the elements of plant fer-y in semi-arid climates.

The phosphoric acid decreased 42 percent in 15 months, and 59 cent in two years. The loss in weight seems to fairly represent the of phosphoric acid.

The great difference between manures in semi-arid and humid nates is expressed in the potash. Practically all who have con-ted experiments along this line mention potash as the most easily of the three elements of plant food, and that it is lost by leaching. r manures retain the potash, probably due to the light rainfall. In first 15 months no loss was found. The second year an absolute of 35 percent of the potash occurred. That the potash in fresh nure is soluble was demonstrated by experiment. Air-dried sheep nure lost 17.8 percent when washed with water, which represents oss of 43.7 percent of the potash, 22.6 percent of the phosphoric d, and 39.0 percent of the nitrogen.

From the 23 analyses of sheep manure, we learn that they con-n on the average 13 percent less moisture than an average of sheep nures in moist climates.

The phosphoric acid remains at about one percent of the dry mat-irrespective of the age of the manure.

The potash in this series of samples increases from an average of . percent in the fresh manures to 6.3 percent in the one-year-old nples, and remains at about this figure for several years, which rroborates the summarized statement in regard to the potash in the terioration experiment.

There is a large loss of total nitrogen during the first two years. most the whole of this loss is due to a loss of free ammonia, which produced in large amounts by the action of uro-bacteria.

The moisture in the manure plays a large part in retaining th free ammonia.

Nitrogen as nitrates varied widely. There was none in the fres manures even after keeping the air-dried samples in the laboratory sev eral years. As much as 27 percent of the total nitrogen was foun present as nitrates in one sample. There was, however, no unifo mity in the results, i. e., some of the older manures carried larg amounts of nitrates while other samples of the same age carried almo none.

The carbon and hydrogen in manures are present in practical constant quantities, the age seemingly having nothing to do with th amount. This was true in both the cattle and sheep manures and i both the soluble ash is nearly a constant quantity.

Taking the results of all the tables as a whole, one is impresse by the sameness of the different determinations; especially is this tru of the soluble ash, the potash, the phosphoric acid, the carbon and hy drogen. It is not true, of course, of the insoluble ash which increas decidedly with age, nor of the free ammonia and nitrogen which de crease with age. This sameness in the results means that, under ou conditions at least, the manure is broken down by bacterial life a about the same rate that leaching carries away the soluble salts.

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

SOME INSECTS AND MITES ATTACKING THE PEACH IN COLORADO

By GEORGE P. WELDON

TWO PLANT LICE OF THE PEACH

By C. P. GILLETTE and GEORGE P. WELDON

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PLATE 1—FIG. 1

FIG. 2

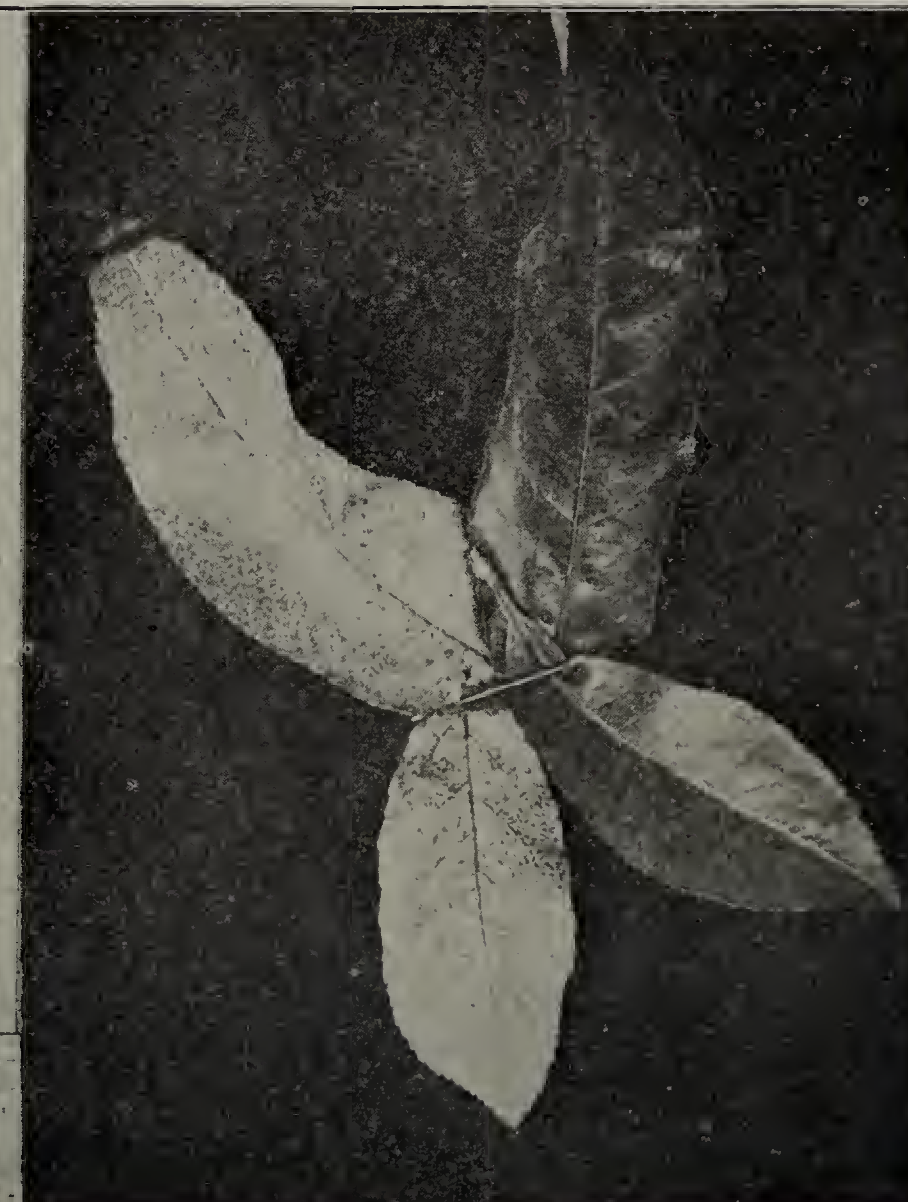

FIG. 3

PLATE 1—FIGURE 1, Peach leaves curled by green peach louse. FIGURE 2, Black peach aphis on twig early in spring. FIGURE 3 shows one green peach leaf and three faded ones caused by attack of brown mites.

SOME INSECTS AND MITES ATTACKING THE PEACH IN COLORADO

By GEORGE P. WELDON

The peach industry in the western slope region of Colorado is one of much importance, and the need for literature treating of a few insect pests and mites that the peach grower must reckon with, seems to be great enough to justify the publication of this bulletin.

The novice in the business of growing peaches in Colorado very often begins with a mistaken notion that peach trees require no spraying. That notion has probably grown out of the fact that in the early history of orcharding in the State, spraying for the control of insect pests was confined almost entirely to apples. While the spraying of peach trees may not be necessary every season, there are times when certain sprays are necessary in order that destructive pests may be controlled. One who hopes to make a success growing high grade fruit must resort to spraying whenever the prevalence of some insect pest demands it. It would not be wise to lay down set rules for the spraying of peaches, for there are too many factors that may bring about a marked increase or decrease in the numbers of certain pests occurring from season to season. For example, last spring a very severe infestation of the common green peach aphis in the peach growing sections of Colorado, made it necessary that stringent methods of spraying be adopted. The previous spring the ocurrence of this pest was very general, but it was not abundant enough in most orchards so that it was necessary to spray for its control. Often a dormant spray of lime and sulphur, or soluble oil is beneficial in orchards where certain pests may be spending the winter. Too much, however, should not be expected of dormant sprays, and while there are insects that they may control very effectively, there are others that will be controlled but partially or not at all. Very often the orchardist who uses a lime and sulfur spray, seems to lose sight of this fact, and because the spray does not meet with his expectations in controlling some certain pest, he condemns it for all of them. As a matter of fact he probably was paid for its use in the destruction of some other pest.

THE PEACH TWIG-BORER (*Anarsia lineatella* Zell)

One of the most common enemies of the peach in the United States, is the twig-borer, or "bud worm" as it is sometimes called. Its occurrence has been reported from most of the peach growing states of the Union, both in the East and West.

In Colorado it has been known for a number of years, and while it is not a seriously injurious pest every season, there are seasons when it becomes exceedingly destructive, and is responsible for a great financial loss to those peach growers who do not adopt proper methods of control.

The adult of the twig-borer is a tiny, dark gray moth. It is an Old World species, supposed to have come to us with the peach from Western Asia, and has been known in the United States since 1860.

Kind of Trees Affected.—The twig-borer is principally an enemy of the peach, and usually we hear of it in connection with its damage to this fruit. It may be found, however, on all stone-fruit trees, but shows a decided preference for the peach. In Bulletin 80, of the United States Department of Agriculture, Dr. Marlatt mentions the pear among its list of food plants. The writer has never noted the attack of this insect upon other than stone-fruit trees. Its occurrence on the pear or other pome fruits is probably rare, and might be compared to the occurrence of the codling moth, which is almost exclusively an enemy of the pome fruits, in plums, peaches, or other stone-fruits. While cases of codling moth infesting stone-fruits in any numbers are rare, they were found the past season, so plentiful in Burbank plums of a certain orchard, that they were really doing considerable damage. The twig-borer, during a season of abundance, might occasionally modify its habits to the extent of an occasional attack upon pome fruits, as the codling moth in a season of abundance may modify its habits and occasionally attack stone-fruits.

The Larvae and Their Injury.—The larvae, as is shown in Fig. 1, hibernate in little silk-lined chambers constructed within the

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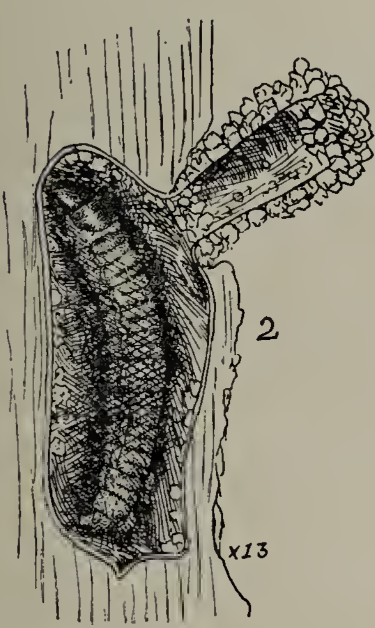
bark and very close to its surface. Mr. Warren T. Clarke, in his bulletin, *states that "in the majority of cases they are found just beneath a thin layer of the greener cells, just below the brown bark, while the greater part of the burrow is in the yellowish portion of the cambium." He also states, in connection with the winter burrow within the bark, that: "The postion generally chosen on the tree for the purpose is the crotch formed where the new wood joins that of the previous year, though older crotches are occasionally selected." In Colorado I have found them almost entirely in the older crotches and always, when found there, they have been in the brown portion of the bark, just as close to its surface as the hibernacula could be constructed. Occasionally the hibernating cells containing larvae, have been found underneath buds on the new growth of peach trees. Their occurrence in this location does not seem to be at all general.

*Bull. 144, Calif. Exp. Sta.

While hibernating the larvae vary somewhat in size, but are all very small, and their detection is somewhat difficult, except when very close observations are made. The presence of the larvae themselves during the hibernating period, could scarcely be detected were it not for the fact that they construct, at the entrance to their burrows, tiny silken tubes covered on the outside with bits of bark, which were chewed off by the larvae while excavating the hibernacula. These little tubes are shown in the crotch of a tree in Fig. 3, and again one is shown at the entrance to a burrow containing larvae in Fig. 2. The larval cell is also lined with silk, the silken tube being merely a continuation of this cell lining. Throughout the winter months the hibernating larvae remain inactive within this



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cell. Apparently no feeding is done after the time that they construct the cells until they leave in the spring, consequently no growth takes place during that time. A hibernating larva, magnified 26 diameters, is shown in Fig. 1. These larvae are exceedingly well protected in their hibernacula, and Mr. Warren T. Clarke's experiments in California show that they are almost impenetrable to even an oil spray during the winter season.

In the spring of the year, about the time the peach trees bloom, the larvae leave their winter quarters and eat into the tips of the twigs, either beginning their work at the extremities or a short distance below, sometimes hollowing them out for usually a distance of less than an inch from where the twig was entered, leaving a mere shell or hollow cylinder of the portion in which they have fed. Again they may merely gouge out the tip of a twig on one side, entering in as far as the pith and then leaving for some other twig. Thus they go from twig to twig, feeding first in one and then in another, until often the tips of a great many branches will be killed back, thereby

checking their growth and more or less injuring the tree. The detection of their work is no difficult matter a short time after they begin feeding, for the leaves of affected twigs soon wilt, as in Fig. 3, and later dry up from the injury done to them.

The injury the first brood larvae do to twigs, while sometimes alarming, is not usually to be compared with the injury to the fruit from the second and third broods. Often this injury to the fruit is extensive enough to render great quantities of it unmarketable, and we have a condition of peaches comparable to that of apples as a result of codling moth attack. The larvae usually enter the fruit from the stem end and may feed entirely within the flesh, but very often they eat their way into the pits. Affected peaches may be detected by an issuance of sap mixed with little pellets from the fruit which have been chewed up by the larvae. This sap hardens on the outside and peaches so effected, are often termed "gummy peaches."

The Pupal Stage.—This stage of the insect is said to last from 6 to 12 days, the first brood remaining pupae for the longest time. This period is passed by the first brood pupae, according to Mr. Clarke, principally in curls of bark on the trunks of trees. They may, however, be found in other places, such as between two peaches which come in contact with each other, under rubbish on the ground, etc. The cocoon which they make is a very flimsy one; in fact, so much so that in reality it should not be termed a cocoon. A few strands of silk are spun by the larvae, and to these strands the pupae is attached by means of hooks at the tip of the abdomen. The second and third brood pupae more often pupate in the suture at stem end of peaches than underneath the bark, and the semblance to cocoons is even less than in the case of the first brood.

The Moth.—The twig-borer moth is a tiny, gray insect, about ¼ inch in length and having a wing expanse of about ½ inch. It is quite a beautiful little moth with its dark gray, fringed wings. They are very seldom seen in the orchards by the fruit growers, because of their small size, their close resemblance to projections of the bark and their habit of resting perfectly still during the day time on the trees.

The Egg.—Eggs of this insect were first found by Dr. Marlatt, who kept the moths in confinement and found that they were deposited above the bases of the petioles of the leaves. Mr. Clarke, in California, found the eggs of the first brood in the orchard, in the same location as described by Marlatt. He found, however, that the eggs of the second generation of moths, were laid not on the twigs, but on the fruit and in the edge of the stem end depression; the eggs of the third generation were found in cracks of the bark, or exposed on its surface, just above the crotches formed by the new wood, and on the old wood.

The eggs are pearly white, changing to a deep yellow before hatching. They are quite conspicuous, being about ⅖ of a millimeter (1/60 of an inch) in length by ⅕ mm. (1/120 inch) in breadth.

These observations of the egg and egg-laying habits of the insect, made in California by Mr. Clarke, are very interesting, as they are the first recorded from studies made under the natural conditions of the orchard.

Experiments for Control of the Twig-borer.—The experiments testing different insecticides for the control of this pest, were all conducted in the spring of 1910, and were combined with the green-peach aphis experiments recorded in this bulletin, with the discussion of the latter pest.

The comparative scarcity of twig-borer the past season made it difficult to secure much reliable data from the experiments. Table I was compiled from data gathered in the W. C. Strain orchard at Clifton, and Table III gives general results of all the experiments in both the Strain and Paxson orchards.

TABLE I.

Results attained with different insecticides in controlling the peach twig-borer, in the W. C. Strian orchard at Clifton, Colo.

Insecticide Used	Strength Used	Date Sprayed	Date Examined	Wilted Tips	Trees Examined
Black Leaf	1–30	March 7	April 26	5	3
Black Leaf	1–40	"	"	6	3
Black Leaf	1–50	"	"	3	3
Black Leaf	1–70	"	"	0	1
Black Leaf "40"	1–600	"	"	0	2
Black Leaf "40"	1 800	"	"	7	4
Black Leaf "40"	1–1000	"	"	6	4
Lime and Sulfur	1–10	"	"	0	12
Lime and Sulfur	1–11	"	"	0	
Soluble Oil	1–20	"	"	4	2
Unsprayed				16	4

While it is not thought that this year's experimental work with twig-borer, would justify the drawing of many conclusions, there were at least some helpful hints gathered in regard to its control. It may be seen from Table I that "Rex" Lime and Sulfur gave perfect results. More trees were sprayed with the "Rex" mixture 1-10 and 1-11, than with any other insecticide, yet in a very careful examination of 12 trees by Mr. Strain and myself, we failed to detect the presence of a single wilted twig because of the work of the borer. On 4 check trees in the same block 16 wilted tips were counted, and on 22 trees sprayed with tobacco preparations and soluble oil, 31 wilted tips in all were counted. One tree sprayed with Black Leaf

1-70 was free from wilted tips, and also 2 trees sprayed with Black Leaf "40" 1-600. The fact that the higher strengths of Black Leaf did no appreciable good, would indicate that it was simply a matter of chance that the one tree sprayed with the weaker strength, indicated good results. Black Leaf "40" 1-600 apparently gave good results, however, because of only two trees having been treated, and because of the scarcity of the twig-borers in the orchard, it would not be wise to draw any definite conclusions without further experiments. The number of trees treated with lime and sulfur and their total freedom from borers, seemed great enough, when compared with the small number of check trees, and other sprayed trees with quite a number of borers, to justify the conclusion that "Rex" lime and sulfur is a perfectly effective spring remedy for this pest. For some unknown reason home prepared lime and sulfur used at the same time as the "Rex" spray, but in another orchard, apparently did little good.

Mr. W. T. Clarke, in Bulletin 144, of the California Experiment Station, at Berkeley, gives some interesting data in regard to sprays applied at different times of the winter and spring, for the control of twig-borer. He found that during the winter season the little larvae, in their hibernating cells, could not be killed either with kerosene emulsion or lime and sulfur. He discovered, however, that the larvae become active in these cells for some time in the spring before emerging, and that during this period of activity the cells are rendered more or less permeable to a spray, and then the larvae can be successfully combated with a contact insecticide. In regard to the effective use of a spring spray of lime and sulfur, Mr. Clarke says:

"The lime-salt-and-sulfur-sprayed trees, when the spraying had been done in the early spring, showed the most satisfactory results of any at the time of examination. On the various station orchards, comprising over 12,000 peach trees, the average number of bud-worms was about one to every ten trees, and this average was maintained on many orchards in the district. Indeed, it was a difficult matter to find the worms in these orchards, and it was only by the closest scrutiny of the trees that they could be located in them. The general condition of these trees was excellent, and a marked absence of 'curl-leaf' was noted.

"An examination of the trees in orchard No. 1, that had been sprayed with the lime salt and sulful early in February, showed that the attack of bud-worms was severe. On many of the trees from which we cut the worms we found from 5 to 9 to the tree. The general condition of the trees was good and a very small amount of 'curl-leaf' was present."

From this season's experiment at Clifton, from the experience

of the many Colorado orchardists who have used lime and sulfur for the control of this pest, and from the apparent success of this spray in California, we feel justified in recommending it for use in the sections of Colorado where there is injury from twig-borer.

While arsenate of lead was a total disappointment in this season's tests, it has previously been used with good success and is, no doubt, effective when applied at the proper time. E. P. Taylor, in his annual report of the Western Slope Fruit Investigations for 1906, gives some very satisfactory results from the use of 5 pounds of arsenate of lead to 50 gallons of water, applied on April 14, at which time the majority of the blossom buds showed their pink tips. Commenting upon the results of his experimental work, he wrote: "It may be said that arsenate of lead, applied in the spring at the time the buds of the peach are beginning to open, will control the peach twig-borer as effectively and cheaply as the lime and sulfur wash, up to this time the most universally used."

THE PEACH TREE-BORER (*Sanninoidea exitiosa*)

Colorado peach growers are fortunate in that they do not, as a rule, have the crown-borer of the peach to fight. In many of the peach-growing sections of the United States, this is one of the worst pests preying upon the trees. Unlike the twig-borer, which feeds upon the tender twigs and fruit, this species feeds just beneath the bark at the crown of trees, often girdling them. The adult insect is a moth which, at a glance, more closely resembles some kind of a bee or wasp, than a moth. The eggs of this moth are deposited on the trunks of peach trees, and the little worm-like larvae hatching from them, eat their way beneath the bark and there feed until full grown.

The work of the insect may be detected by masses of gum in which are mixed pellets of wood or borings which the larva chews to pieces as it feeds. These gum masses usually occur at, or just below the ground line. Their presence aids in the fight against this pest, as the burrows in which the larvae feed can always be found beneath. By using the point of a knife or a piece of wire, this burrow may be followed and the larva located and killed. No better method for combating the peach tree-borer has ever been devised than worming, as the above process is called, with a knife or some other implement that can be inserted into the burrow. Worming should be done both in the fall and spring. While the larvae often do not attain a sufficient size in the fall to be readily detected, a great many of them can be killed before they get in very far, thus preventing the damage that they might do before they could be detected in the spring.

Various other methods of control have been tried, such as wrapping the trunks with tar paper to keep the moths from deposit-

ing their eggs, applying repellants for the same purpose, and mounding the soil up above the crown of the tree. This last named method is valuable in that where it is used the larvae may be induced to enter the trunk of a tree some distance above the surface of the ground, then when the mound is removed the worms are high on the trunk, where they can be much more easily destroyed than if they were lower down.

SCALE INSECTS.

It is very fortunate that none of the scale insects have as yet been found abundantly on peach trees in Colorado. The San Jose scale has been seen on a very few trees, but not plentiful enough to do any serious injury. This pest seems to confine its attacks more to the apple in the few orchards where it has been found.

In one section of the Grand Valley a scale insect closely allied to the dreaded San Jose is found. Samples of this scale were sent to Prof. T. D. A. Cockerell, Entomologist in the State University at Boulder, who kindly determined it for me as the putnam scale. Only in rare cases has this insect been found doing serious injury.

There are other scales of minor importance that are sometimes found on peach trees; all of these insects may be successfully combated with an early spring spray of lime and sulfur, or soluble oil. If Rex lime and sulfur is used it should be diluted by using 1 part of the Rex solution to 10 parts of water. A good home-made lime and sulfur is as effective as the Rex, and should be made with 20 pounds of lime and 15 pounds of sulfur to 50 gallons of water. Soluble oil is ordinarily used at a strength of one part of the oil to from 15 to 20 parts of water.

While spring spraying for the control of these scale insects is probably more advantageous than a spray at any other time, good work can also be done with a fall application. Very often orchardists would rather spray in the fall because there is more time to do so than in the spring.

THE BROWN MITE (*Bryobia pratensis* Garman)

In Bulletin 152, of this Experiment Station, an account was given of the life habits and injuries from this species of mite, and also the red spider. As this bulletin is still available it will not be necessary to again give a detailed account of these two pests.

This mite passes the winter almost entirely in the egg stage. These eggs are tiny, red spherical-shaped, glassy objects, usually deposited in or near crotches of the branches. Hatching takes place in the spring. At first the young mites are red in color and have only six eggs. Upon feeding for a short time moulting takes place, after which the mite is olive green, or brown in color, and has eight legs more or less tinged with red. It feeds principally upon the leaves, occasionally attacking the fruit, and may be detected by the

faded out, pallid appearance of the foliage, dotted here and there with little black specks of excreta. Plate I Fig. 3 shows two peach leaves which have been attacked and two which are normal from the same tree, and gives a good idea of their appearance after this pest has been feeding upon them.

Control Measures.—Experiments recorded in Bulletin 152 show that tobacco preparations are of little value in controlling this mite; that they will kill the mites, but not the eggs. As the latter are almost always present on a tree where the mites are feeding, such sprays can only be effective when repeated applications are made. The sulfur spray was again tested this season, this time at Palisade, Colorado. Some badly infested pear trees were treated, using 10 pounds of sulfur to 50 gallons of water. Results of this test were perfect, and a week after the trees had been sprayed it was hard to find a living mite on them.

An interesting point in connection with the sulfur treatment for brown mite is: The adult mites are not immediately affected by the spray, but those newly hatched die shortly after the application. An examination of a tree the day after spraying with sulfur is usually disappointing, for the adult mites may be alive and abundant. In all the tests made a very few newly hatched, six-legged mites have been found, 24 hours after spraying, and in a week's time neither adult nor newly hatched mites can be found. The sulfur adhering to the bark and leaves, undoubtedly kills the young mites as they hatch from the eggs. Whether the older ones are killed by the sulfur or simply die a natural death is a point that has not been determined definitely. As there are probably only three broods of this mite, and they are quite long lived, it would seem that the sulfur really kills the adults, but that it takes some days to do so. The important fact remains that the young mites never develop after the sulfur treatment, whether hatched or in the egg stage at the time of treatment, and that the adult mites are either killed by the sulfur or die a natural death within 7 or 8 days after treatment, thus ridding infested trees of the pest.

Lime and Sulfur an Efficient Remedy.—In Bulletin 152 the following statement was made: "Trees may be treated while dormant with lime and sulfur. This spray has no effect upon the eggs, but probably kills the young mites as they hatch." The fact that the lime and sulfur kills the young mites as they hatch was definitely established last spring at Palisade, Colorado.

Three adjoining peach orchards, each containing a great many brown mite eggs—two of them sprayed with Rex lime and sulfur 1-10, and one not sprayed—were chosen as observation places to determine this point. The eggs were found hatching in all three orchards at the same time; in the orchards which were sprayed a great

many of the tiny, red mites could be found where they had died on the limbs very soon after hatching. In no case were any found alive, except a few immediately hatched from the eggs. In the unsprayed orchard all the mites seemed to live and the trees were soon covered with them. Throughout the season the sprayed orchards were almost entirely free from mites, while the unsprayed one, located between the other two, had quite a serious infestation.

As a result of the extensive use of a lime and sulfur spray in the Palisade section the past season, the brown mite was practically exterminated, except in a few orchards where such a spray was not used.

THE RED SPIDER *(Tetranychus bimaculatus)*

This mite differs from the preceding one in its wintering habits; instead of living over in the egg stage, as the brown mite does. this species hibernates in the soil as an adult, close to trees upon which it has been feeding, or underneath rubbish of any kind. On the 7th of November, this season, they were found plentifully, under burlap bands that had been applied to trees for the purpose of trapping the codling moth larvae. Hibernation begins before the cold weather sets in; the first downward migration of mites to the soil was noticed at Grand Junction, this season, on July 26. While a few of them may work on trees until late in the fall, their damage is usually over by the 15th of August.

Eggs are laid in the spring by mites that have lived through the winter. These eggs are pearly white, and may be seen as tiny specks on the under surface of the leaves.

When first hatched from the egg this mite, like the species previously treated, has only six legs, the fourth pair developing with the first moult. They are somewhat smaller than the brown mite, usually green in color while feeding upon the foliage of trees, with minute black dots on the dorsum of the abdomen. When feeding ceases in the fall, and they begin their downward migrations to the soil, they become an orange, or red color. During my observations of this species of mite, for the past three years, a red one has never been seen on fruit trees until feeding ceases in late summer. In greenhouses this same species is very often red in color. Unlike the brown mite, the red spider has the power of spinning a web, and may easily be detected, when prevalent, by the presence of these webs on the foliage, or branches of infested trees. The appearance of injured peach foliage is not unlike the appearance of that injured by the brown mite, but is more inclined to turn yellow in patches.

Control Measures.—Sulfur is very successful in treating this mite also, whether dusted upon or applied as a liquid spray to infested trees. When applied in water, by means of a spray, sulfur should be very finely screened, and mixed with the water by using

a small amount of soap. Without the soap the sulfur will remain on the surface of the water, while with the soap it will sink to the bottom of the spray tank, and a good agitator will keep it mixed.

Lime and sulfur has not proven a successful treatment for red spider, and cannot be depended upon to do effective work when used as a dormant spray.

The use of tobacco preparations, as with the brown mite, result in little good.

TWO PLANT LICE OF THE PEACH

By C. P. GILLETTE and GEORGE P. WELDON

THE GREEN PEACH APHIS (*Myzus persicae* Sulz)

This is the common green peach louse so prevalent early in the season curling the leaves and often attacking the blossoms and forming peaches in a most destructive manner.

This insect was quite fully treated and figured in its natural colors in Bulletin 133 of this Station, by Gillette and Taylor. Copies of this bulletin are still available for those requesting it.

How the Winter Is Spent.—The eggs of this species of plant louse are deposited on peach trees, (occasionally on other stone fruit trees), in the fall, where they remain unhatched until early spring. Their detection is not as easy as that of the common green apple aphis egg, but is not extremely difficult when one knows where to look for them. Last fall the eggs were deposited in such large numbers that they could be easily found in a great many orchards. In some cases the buds of peach twigs were dotted black with them. Usually these eggs are deposited on, or very close to a bud, (See Fig. 4), and very often just as deep in wrinkles or depressions as possible, and unless they are plentiful, it may require sharp eyes to detect them. When first deposited, the eggs are light green in color, turning black after exposure to the air. They are much smaller than the eggs of the common green apple aphis, which nearly every orchardist has seen, but are quite similar in shape, color and general appearance. This pest may live over winter on vegetation that remains green throughout the winter season, so there would be a possibility of trees becoming infested at least late in the season from other sources, even though the eggs were all killed by an insecticide, or failed to hatch because of unfavorable weather conditions or other causes.

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The eggs of this aphis hatch very early in the spring. E. P. Taylor reports having found them hatching at Grand Junction, Colorado, on the 16th day of February, 1907. The month of February that winter was unusually warm and the extremely early hatching of the eggs was due to that fact. However, hatching takes place when the buds have scarcely begun to swell, a fact which is not generally understood by the fruit grower, and one which is of very great importance in its relation to the control of the pest by means of a spray. The past spring, eggs were found hatching on the 7th of March at Clifton, Colorado, at which time the buds seemed perfectly dormant.

Spring Habits.—When first hatched from the eggs these aphids are dark green in color, and may be seen as tiny, dark specks crawling along the twigs, or more often, clinging to the buds. It is probable that they can exist for a number of days after hatching with little or no food. What feeding they do takes place on the buds or very tender bark into which their beaks are inserted, and from which a portion of the early flow of sap is extracted. Plant lice of the spring brood, which hatch from eggs that have remained on trees over winter, are known to the entomologist as stem-mothers. The full grown stem-mothers of this plant louse are of a pinkish or salmon color, and before there is a sign of a peach blossom in the spring, these stem-mothers have begun reproduction. Their progeny are born alive, eggs never being laid except in the fall, and then by an aphis which, though only a different form of the same species, might be taken by the orchardist for an entirely different kind of plant louse. The generation from the stem-mothers differ from the latter in that they are light green in color, with darker green, longitudinal markings on the dorsal surface of the abdomen, but are never pink like the stem-mothers. Just as soon as the buds on infested trees begin to unfold, the stem-mothers, with their progeny, are ready to enter within. At first they seem to prefer feeding in the blossoms, but after these fall, quite serious injury is often done by their feeding on the leaves. Probably the greatest injury to peaches resulting from their attack, consists in the dropping of the small fruit which has become devitalized from the loss of sap until it can make no growth, hence shrivels and falls to the ground. The injury to the peach is practically all done while it is yet in the husk or calyx tube. After the peach has cast off this calyx tube it is not likely to be molested further by the aphids, and unless it has been too much weakened before this time, the probabilities are that it will not drop as the result of aphis attack.

Summer Habits.—Fortunately this pest cannot, or does not, spend its entire existence upon the peach or other trees, but leaves them for more succulent vegetation. Shortly after the peaches are

formed, winged lice begin to appear in the colonies; these fly away to other food plants, and by the last of June very few can be found on peach trees. This is indeed a blessing to the peach grower, for should this pest continue its ravages throughout the summer on the peach, it would require great effort and expense to control it. As it is, trees often suffer a great loss of foliage, and if it were not for the wonderful power of the peach tree to recover after this injury, the result of the aphis attack would be more disastrous.

Gillette and Taylor, in Bulletin 133, of the Colorado Experiment Station, gave a list of 53 plants growing in the greenhouse, which were found to be infested with this aphis, and 25 plants growing out of doors, the out-of-door plants comprising most of the common garden vegetables and weeds. The variety of plants upon which this louse feeds during the summer time is so great that it is probable that it will seldom be plentiful enough on any one kind to do serious injury. While on the summer food plants, this aphis is usually light yellow in color, and without the green stripes so characteristic of it while feeding on the peach.

Fall Habits.—The last winged generation of lice appearing in the fall are known as fall migrants, because of the fact that they leave the vegetation upon which the summer has been spent and migrate to peach trees. These fall migrants do not deposit eggs, but give birth to the true sexual forms, males and females. The females are pink in color, somewhat similar to the stem-mothers which were on the trees in the spring, but smaller. After feeding for a time and becoming mature they deposit the eggs previously described.

Spraying Experiments.—Because of the abundance of green peach aphis eggs last winter, a number of different tests were made in the spring, with various insecticides, in order to determine their value as egg destroyers. The spraying was delayed a little too long, however, and on the 7th of March, when the first applications were made in the W. C. Strain orchard at Clifton, many of the eggs were found to be hatching, and there was no trouble in finding the little green lice here and there on the twigs. A great many of the eggs were not hatched at that time, hence the various sprays were tested as destroyers of both the eggs and the young lice. The block of trees sprayed in the Strain orchard, was only three years old, but contained both the eggs of green peach aphis and the hibernating larvae of the twig-borer in abundance. The small size of the trees made very thorough spraying possible. The work was done with a Morrill and Morley barrel pump, so it was not possible to make the applications with a high pressure. Thoroughness was depended upon to compensate for the deficiency in pressure. Tests were made in this orchard with Rex lime and sulfur, two strengths, namely: 1 gallon

of the "Rex" to 10, and 1 to 11 gallons of water; Black Leaf tobacco extract, four strengths, namely: 1 gallon to 30, 1 gallon to 40, 1 gallon to 50, and 1 gallon to 70 gallons of water; Black Leaf "40," three strengths, namely: 1 gallon to 600, 1 gallon to 800, and 1 gallon to 1,000 gallons of water; soluble oil, 1 strength, namely: 1 gallon to 20 gallons of water. Thirty-eight trees in all were sprayed in this test, and 5 were left without any treatment, for checks.

On the 8th of March, 21 trees were sprayed in Mr. M. Paxson's orchard at Clifton. These trees were five years of age, and fully as many eggs of the aphis, and larvae of the twig-borer were found on them as in the Strain orchard. The following insecticides were used on this date: Nico-fume at two strengths, namely, 1 gallon of Nico-fume to 600, and 1 gallon to 800 gallons of water. Kerosene emulsion was applied at one strength only, namely, a 15 per cent. oil emulsion prepared by using a common laundry soap. Black Leaf was applied at one strength, namely, 1 gallon to 55 gallons of water. Home prepared lime and sulfur was applied at one strength, namely, 15 pounds of lime and 15 pounds of sulfur to 50 gallons of water. This lime and sulfur was made in the ordinary way, and was boiled for one hour, so that a first class lime and sulfur spray was prepared.

On March 28th the peach buds were just showing their pink tips, and several sprays were again applied. At this time three of the tests were made with a mixed spray of arsenate of lead and one of the tobacco preparations, the arsenate of lead being used for the twig-borer, and the tobacco preparation with which it was mixed, for the aphis. The following insecticides were applied at this time to about 150 trees: Rex lime and sulfur, 1 gallon to 10 gallons of water; Black Leaf, 1 gallon to 50 gallons of water; Black Leaf, 1 gallon to 70 gallons of water, combined with arsenate of lead 3 pounds to 100 gallons of water; Black Leaf "40," 1 gallon to 800 gallons of water; Black Leaf "40," 1 gallon to 1,000 gallons of water, combined with arsenate of lead 6 pounds to 100 gallons of water; Black Leaf "40," 1 gallon to 900 gallons of water, combined with arsenate of lead 10 pounds to 100 gallons of water.

Results of Experiments.—Table II gives the results of the first examination made on March 15, of trees sprayed in the Strain orchard. It may be seen from this table that all insecticides applied on March 7th resulted in effective control, at all strengths. Subsequent examinations were made on March 24th, April 26th, and May 11th, each one indicating practically the same results. It would seem from this experiment, that just as the eggs of this aphis are beginning to hatch is a favorable time to spray for its control. Lime and sulfur proved to be a perfect spray at this time. Appar-

ently, it gave a little better final results than anything else used. Table III gives a summary of results in both the Strain and Paxson orchards. It may be seen from this table that, with the exception of Nico-fume, all the tobacco sprays of both early and late applications resulted in much good, but that lime and sulfur applied on the latest date of spraying did not prove beneficial. This application of lime and sulful was made at a time when some of the first lime and sulfur spraying was being done in the Valley, but earlier than much of it. The experience of most of the orchardists was: that the lime and sulfur did no good applied late for green peach aphis, which tallies with our experience. This season's experiments indicate that the most important thing in connection with the control of this aphis by the use of lime and sulfur, is to get it on early; just as the eggs were beginning to hatch was found to be a splendid time. If spraying is delayed until the aphis becomes full grown, some other spray besides the lime and sulfur should be used. This spray will not kill the mature stem-mothers unless applied in excessive quantities.

The tobacco sprays are much better to use when mature lice can be found. But these preparations are also more effectual at the time when the eggs are hatching. A great amount of material is required in order to be thoro enough to kill most of the lice after they are fully grown.

The average orchardist would probably have a hard time to detect the little lice when they are first hatched, but the importance of spraying at this time should be sufficient reason for him to learn to find them. If this is not possible it would be reasonably safe to say that the lice may be found hatching after the first few days of warm spring weather in February or March, in the vicinity of Grand Junction, and that a spray at such a time would be successful. A hand lens, costing 25 to 50 cents, is of great service in finding the lice.

On March 25th some large Triumph peach trees were sprayed on the C. H. Dilley place at Clifton. These trees had been sprayed a few days previously with lime and sulfur, but apparently with no success in killing the aphis, which at this time were clinging to the partially open blossoms waiting for a chance to get within. Part of these trees were treated with Black Leaf, 1 gallon to 70 gallons of water, and the rest with Black Leaf "40," 1 gallon to 800 gallons of water. By exceedingly careful and thoro spraying, entailing the use of at least ten gallons of spray to a tree, it was found that practically all the lice could be killed. The Elberta trees in this orchard did not have so many of the aphids on them, and the manager of the place decided that they did not need to be sprayed. On May 11th an examination of these trees showed the Elbertas to be badly in-

fested, and the Triumphs, which we had sprayed, were exceedingly clean. The difficulty experienced in spraying trees so late in the season, lies in the fact that the leaves always tend to curl and provide such protection for the lice, that only the most thoro work can result in much good.

THORONESS NECESSARY TO SUCCESSFUL SPRAYING.

No matter when the spraying may be done for the control of this insect, success cannot be attained unless a very thoro application of the insecticide is made. In fact, this is a general rule that will hold good in spraying for the control of all insect pests. While this point is always emphasized by entomologists, our experience with orchardists has been that many do not have a proper conception of what thoro spraying means. This may be due in part to the failure to appreciate the fact that insects multiply tremendously in a short time, and unless a spray kills practically all of a pest, such as the one in question, a few days or weeks may see them as plentiful as they were before the spray was applied. Spraying investigations in the orchard indicate, also, that much of the trouble is due to the expense of a proper treatment. Most of the insecticides used are very high priced, and the orchardist does not feel that he can go to the expense necessary to thoroly treat his trees. He very often fails to realize that work such as this, half done, is really work wasted, to say nothing of the expense.

It is safe to say that spraying for the control of the green peach aphis can only be successful when very great care is used to thoroly drench every portion of infested trees.

CONCLUSIONS.

1. Lime and sulfur, both Rex and home prepared, Black Leaf extract, Black Leaf "40," and soluble oil, may be effectively used for the control of the green peach aphis when applied in the early spring just as the eggs are hatching.

2. A lime and sulfur spray is not effective when applied two weeks or more, after the eggs are hatched, for at this time the stem-mothers are mature, or nearly so, and are able to resist the action of this insecticide.

3. Good tobacco preparations may be used with success any time after the aphids hatch, but it is more difficult to succeed late in the spring, because it is then more difficult to get the spray on all the lice, on account of the protection of the leaves.

4. The best time to spray for this insect is in the early spring when the eggs are hatching.

Table II, giving results attained in killing eggs and newly hatched lice of the green peach aphis on small trees in the W. C. Strain orchard at Clifton:

TABLE II.

Insecticide Used	Strength of Insecticide	Date of Spraying	Date of Examination	No. of Aphids on 6 Twigs From 2 Trees
Black Leaf	1–30	March 7	March 15	2
Black Leaf	1–40	"	"	2
Black Leaf	1–50	"	"	1
Black Leaf	1–70	"	"	1
Black Leaf "40"	1–600	"	"	0
Black Leaf "40"	1–800	"	"	6
Black Leaf "40"	1–1000	"	"	7
Rex Lime and Sulfur	1–10	"	"	1
Rex Lime and Sulfur	1–11	"	"	2
Soluble Oil	1–20	"	"	0
Check				93

TABLE III

Insecticide Used	Strength	Date of Spraying	General Results in Killing Aphis		General Results in Killing Twig-Borer	
			Early Spray	Late Spray	Early Spray	Late Spray
Black Leaf	1-30	March 7	Good	----	Unsatisfactory	------
Black Leaf	1-40	March 7	Good	-----	"	------
Black Leaf	1-50	March 7 and 28	Good	Good	"	Unsatisfactory
Black Leaf	1-70	March 7 and 28	Good	Good	Apparently good but not enough trees	"
Black Leaf "40"	1-600	March 7	Good	----	Good	------
Black Leaf "40"	1-800	March 7 and 28	Good	Good	Unsatisfactory	Unsatisfactory
Black Leaf "40"	1-1000	March 7	Good	----	"	-----
Nico-Fume	1-600	March 7	Poor	----	"	------
Nico-Fume	1-800	March 7	Poor	----	"	------
Soluble Oil	1-20	March 7	Good	----	"	------
Ker. Emul	15[redacted] 1	March 7	Poor	----	"	------
Rex Lime & Sulfur	1-10	March 7 and 28	Good	Unsatisfactory	Good	Unsatisfactory
Rex Lime & Sulfur	1-11	March 7 and 28	Good	Unsatisfactory	Good	------
Lime and Sulfur	15-15-50	March 7	Good	----	Poor	Unsatisfactory
Black Leaf / Arsenate of Lead	1-70 / 3 lbs. to 100 gals	March 28	-----	Good	----	"
Lead Arsenate / Black Leaf "40"	10 lb-100 / 1-900	March 28	-----	Good	----	"
Black Leaf "40" / Lead Arsenate	1-1000 / 6 lb-100	March 28	-----	Good	----	"

BLACK PEACH APHIS *(Aphis persicae niger)*

This enemy of the peach has never been of much economic importance in Colorado. It has been found from time to time, in the peach growing sections of the Western Slope, but apparently has not been able to continue for any length of time in orchards where it has been introduced. Notwithstanding the fact that up to the present time it has never made any headway in the orchards, it is well for the peach growers not to take any chances in orchards where it does appear, but to be prompt in making a very thoro application of Black Leaf, or some other good contact spray to infested trees.

The fact that this pest has the habit of feeding upon the roots as well as the twigs of peach trees, makes it one that is dreaded. Because of its ability to live below as well as above ground, it might become a serious pest if conditions should happen, at any time, to be favorable to its development.

Very often peach nursery stock coming from an infested nursery, is found to be badly infested with this aphis. When such trees are found they should be either carefully fumigated with hydrocyanic acid gas, or sprayed with a good contact insecticide such as Black Leaf, kerosene emulsion, or whale-oil soap. Plate I, Fig. 2 shows a section of a peach twig on which is a large number of these aphids. This twig was cut from a tree which had just been removed from a box shipped into the state from an outside nursery. There were so many aphids in the box that they found their way through the cracks and could actually be seen crawling on the outside in considerable numbers. The box bore a fumigation tag and the inspector, whose duty it was to look over all shipments of nursery trees into the county, rightly condemned all the trees in the box. The dark color of the adult lice and their habit of feeding on the tender bark rather than the leaves enables us to separate this louse readily from the foregoing species.

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The Agricultural Experiment Station

OF THE

Colorado Agricultural College

THINNING THE WINESAP

Winter and Frost Injuries of Fruit Trees

BY

R. S. HERRICK

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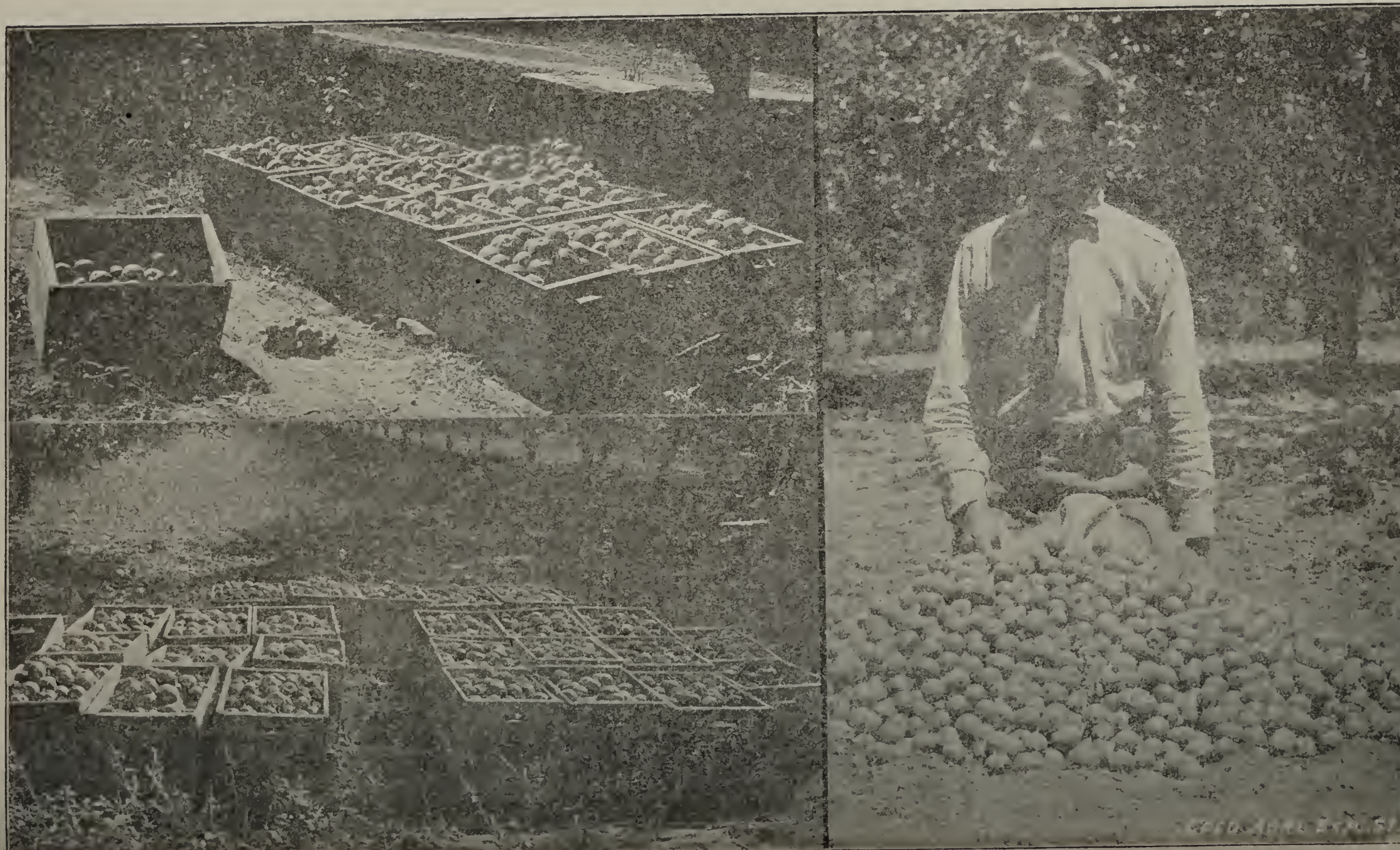

Fig. 1. (a) Apples from thinned tree No. 6. Note small pile of culls.
(c) Apples thinned off tree No. 6.

THINNING OF THE WINESAP

By R. S. HERRICK

The Winesap apple, as a rule, does not attain sufficient size to meet the requirements for packing in the higher grades. This is especially true of heavily loaded old trees. It is not a "shy" bearer, but has a tendency to bear a heavy crop every year.

At a meeting of the representatives of the leading fruit growers' associations of the State, held at Grand Junction in February, 1910, rules were made and adopted for the grading of apples, which were as follows: "That the grade names be designated as 'Extra Fancy,' 'Extra Choice,' and 'Standard.' That the Extra Fancy grade is to include perfect apples, free from all blemishes, not less than 2½ inches in diameter for all varieties and of normal color, and layered throughout the box. That the Extra Choice is to include apples of not less than 2¼ inches in diameter and containing no worm holes and layered throughout the box. That the Standard grade be left to the discretion of the respective shippers." The Standard grade as packed by one of the leading fruit growers' associations of the State is as follows: "Pack in this grade all apples lacking in color or shape and pack nothing less than 2¼ inches in any variety. One small worm hole in side or end is allowed, but no more. If a worm hole is surrounded by a large discoloration, cull the apple. Leaf-rubbed or limb-scarred fruit, or fruit having two or three worm-stings is admissible."

It will be seen from the above rules that great care must be taken in the handling of the standard varieties of our apples, and in tending the orchard, to maintain a high grade of fruit. Among other things, careful attention must be given to the pruning, thinning, spraying, fertilizing, cultivating and irrigating. All of these are important factors in the management of an orchard; and, particularly with the Winesap, thinning should rank high among the requirements for best results. While every orchardist wishes to get the best possible yield for the season, at the same time it is better to have an average yield every season than a heavy crop one season and nothing the next. It is not claimed that thinning alone will attain this end, but there is no doubt that it will play an important part in doing so. If a tree will show a marked gain in value received from only one year's thinning, then it is important that the operation be continued.

In this bulletin the thinning of the Winesap will be discussed more fully than that of any other variety. A block of Winesaps and Jonathans was secured for a thinning experiment, in Mr. A. L. Robert's orchard at Paonia, Colorado. The Winesaps were about thirteen years old, set in rows running north and south, with the

trees 16 by 32 feet apart. The Winesaps in the rows alternated with fillers mostly of Missouri Pippins and Wagners and a few Jonathan apple and Elberta peach trees. This orchard has a very good soil for fruit trees and the Winesaps are of good size for their age.

TIME OF THINNING.

Ten trees were selected that had from a fair to a very heavy load of apples which were about three-quarters of an inch in diameter. Six of these trees were thinned on June 16th, 17th and 20th. This was done just as soon after the "June drop" as it was possible to tell what fruit would stick. The earlier in the season after the "June drop" that thinning of the Winesap can be done, the better it will be for the tree and remaining apples.

The mid-summer thinning was done on July 22nd. Only two trees were thinned, and although the per cent. of the better grades was as good as from the June thinned trees, it might not have held good if more trees had been thinned at that time. The extra amount of plant food that is utilized by the apples which remain on an early thinned tree, after part of them have been taken off, induces a growth that could not be made by the same number of apples left on a tree after thinning late in the season. This is one of the chief reasons why thinning of apples should be done just as early as possible. There have been various attempts to thin the bloom instead of the apples, after they have set, but at present no method has been devised whereby this can be successfully done. This would be hard to do, and undesirable, where killing spring frosts are liable to occur.

THINNING WINESAP—SEASON 1910.

Tree No.	No. Apples Thinned Off		Windfalls Before and At Picking Time				Total No. Apples Picked Per Tree		Total No. Borne Per Tree	Thinning Distance in Inches
	Date	No.	Date	Before	At Picking	No. Boxes	Boxes	Apples	Apples	
1	6-16	3167	10—7	93	18	.5	20.5	3391	6669	About 10 except in top
2	6—16	2550	10—7	76	47	.5	21.5	3526	6199	6 to 8
3	6—17	2150	10—7	101	4	.5	18	3134	5389	8
4	6—17	1000	10—8	48	12	.3	10	1908	2968	10 to 12
5	6—17	1980	10—8	58	40	.5	14	2155	4233	About 8
6	5—20	3250	10—8	52	43	.5	14	2036	5381	10
7	7—22	2033	10—8	40	15	.25	12	1711	3799	8 to 10
8	7—22	3060	10—8	75	21	.5	14	2371	5527	6 to 8
Check 1	------	------	10—10	246	133	1.25	26	6293	6672	Not Thinned
Check 2	------	-----	10—10	312	71	1.25	16	3249	3632	Not Thinned

RECORD IN PACKING HOUSE.

(NO WINDFALLS TAKEN TO PACKING HOUSE.)

Tree No.	No. Picking Boxes	PACKED OUT BOXES GRADED						Total Boxes Culls with Windfalls
		Ex. F.	Ex. C.	Standard	Three Grades Total	Culls	Four Grades Total	
1	20.5	7.5	3	5	15.5	.62	16.12	1.12
2	21.5	7.12	6.5	4.5	18.12	.75	18.87	1.25
3	18	4	5.25	3.66	12.91	1.66	14.57	2.16
4	10	2	1.33	4	7.33	.33	7.66	.63
5	14	3	3.66	3	9.66	.5	10.16	1
6	14	6.5	2	1.87	10.37	.5	10.87	1
7	12	5.5	1	1 12	7.62	.5	8.12	.75
8	14	7.12	1.8	2.5	11.42	.5	11.92	1
Check 1	26	2	0	12	14	6	20	7.25
Check 2	16	3	2	6	11	1.66	12.66	2.91

THE PER CENT. PACKED OUT FOR EACH TREE FOR THE FOUR GRADES.

Tree No.	In Packing House, Not Counting Windfalls					Grand Total No. Packed Out Boxes and Per Cent. for Each Tree, Counting all Windfalls					
	Four Grades Total Boxes	Per Cent. Packed Out in Different Grades				Wind-falls—No. Boxes	Total Boxes	Per Cent. for Each Tree			
		Ex. F %	Ex. C %	Stand.%	Culls %			Ex. F %	Ex. C %	Stand.%	Culls %
1	16.12	46.21	18.61	31.01	3.84	.5	16.62	45.12	18.05	30.08	6.75
2	18.87	37.73	34.44	23.84	3.97	.5	19.37	36.77	33.55	23.23	6.45
3	14.57	27.45	36.03	25.12	11.39	.5	15.07	26.54	34 84	24 29	14.33
4	7.66	26.1	17.36	52.21	4.3	.3	7.96	25.12	16.71	50.25	7.91
5	10.16	29.43	36.02	29.43	4.92	.5	10.66	28 07	34.35	28.07	9.40
6	10.87	59.79	18.39	17.2	4.59	.5	11.37	57.17	17.59	16.44	8.80
7	8 12	67.73	12.31	13.79	6.15	.25	8.37	65.71	11.94	13.38	8.96
8	11.92	59.73	15.1	20.97	4.19	.5	12.42	57.33	14.50	20.13	8.05
Check 1	20	10	.....	60	30	1.25	21.25	9.41	......	56.47	34.12
Check 2	12.66	26.69	15.79	47.39	13.11	1.25	13.91	21.56	14.38	43.13	20.83

AVERAGES.

	Average No. Picking Boxes to Tree	Average No. Packed Out Boxes to Tree					
		Ex. F	Ex. C	Stand.	Total 3 Grades	Total Culls	Total to Tree
Thinned	15 08 eight trees	5.34	3.07	3.20	11.61	1.11	12.72
Unthinned	22.25 two trees	2.5	1	9	12.5	5.8	17.58

OR IN PER CENT.

	Average % of Packed Out Boxes to Tree in Different Grades					
	Ex. F %	Ex. C %	Stand. %	3 Gr'd's %	Culls %	Boxes
Thinned	41.98	24.14	25.15	91.27	8.72	12.72
Unthinned	14.22	5.69	51.19	71.10	28.89	17.58

DISCUSSION OF TABLES.

Windfalls.—In figuring the total per cent. of the different grades borne by each tree, the thinned off apples were not counted. The windfalls were all counted as culls, for it is a well known fact that when an apple falls to the ground, from any cause, it generally bruises so that it has to be thrown into the cull box.

It will be seen that the average number of windfalls per tree before picking, was 68 apples for the thinned and 279 apples for the unthinned trees. The average number of apples which fell to the ground while picking was 25 from the thinned, and 102 from the checks or unthinned trees. The total average number of apples which fell to the ground was 93 from the thinned trees and 381 from the unthinned, making about four times as many fallen apples per tree for the checks or unthinned, as for the thinned trees. The number of apples which fell while picking was 77 less per tree for the thinned trees than for the unthinned. When the apples are in clusters at picking time, it is impossible to keep from dropping some on the ground, and the more clusters there are the greater will be the number that fall. The figures show there were about four times as many apples dropped from the unthinned as from the thinned trees.

Culls.—Apples which come under this head were those less than 2¼ inches in diameter, those badly bruised or scarred, and those very wormy. In connection with this it might be well to state that the Winesaps in the experiment were from 5 to 7 per cent. wormy. This worminess had some effect on the per cent. of boxes packed in the different grades, and as the unthinned fruit was more wormy, because of the clusters affording favorable places for the young codling moth larvae to gain an entrance to the fruit, the number of culls due to codling moth, would be proportionately greater from the unthinned trees.

Many of the apples "culled" were those that were limb-bruised because of their rubbing against some limb. Those apples growing on the terminals of long, slender branches were often badly limb-bruised, caused by being knocked about in the wind. Proper pruning and thinning does away largely with these abrasions.

Thinning Distance.—To thin the fruit on a tree and leave the apples a definite distance apart is a difficult matter. A keen eye and experience are required for the best results. One may think that he is taking off too many apples, or whatever fruit he is thinning, and that he is ruining his crop, but at picking time he generally wishes that he had taken off more. A good motto to go by in thinning is: "Look up, not down." In other words, pay no attention to the apples on the ground, but be sure that every branch is thinned

to such an extent that it will not only be able to properly support a load of mature fruit, but will also be able to grow it to proper size and color. Because one side of a tree is light and the other side heavy with fruit is no reason why the heavy side should not be thinned. The physiology of a tree is such that the food supply for one side or part of it, is largely independent of the other parts. For example, one side or part of a tree may be dead because of the death of the roots which fed that part of the tree. This is perhaps more often true of old trees than of young ones.

It may be seen from the table that the apples of tree No. 1 were thinned to about 10 inches, except in the top, and it was due to this fact that the small apples were found in that portion of the tree. Because it was hard to tell exactly the distance that the fruit was thinned on each tree, the distances given are more or less estimated.

A study of the individual tree is necessary in order that one may be able to thin it in such a manner as to get the best results. Trees of the same variety and age, may vary in their productiveness in the same orchard, and for this reason it is a good plan to study each tree for several seasons to be able to ascertain its wants and requirements. In averaging the total number of apples borne by each tree, it will be seen that this average is about the same for the thinned as for the checks or unthinned trees. These average totals are 5,021 apples for the trees that were thinned, and 5,152 apples for the checks or unthinned trees. These averages per tree include all of the apples that were set at thinning time.

The average per tree for the number of apples at picking time, including all windfalls, was for the thinned 2,622, and for the unthinned or checks 5,152 apples. From these figures it may be seen that about one-half of the apples were removed from thinned trees. The average estimated distance apart of all apples on thinned trees was 8¾ inches. In examining the apples at picking time, it was found that as a rule, better apples, in regard to size and color, were found on limbs where they had been thinned to about 10 inches. It is believed that the very best results from thinning old, heavy bearing Winesap trees, would be obtained by thinning the apples uniformly to a distance of from 9 to 10 inches as soon as possible after the "June drop."

Cost of Thinning.—In this experiment an average of about 750 apples per hour were thinned from the trees. This would make 7,500 apples for a day of ten hours. Counting 2,400 apples to be thinned from a tree, one man would thin 3⅛ trees per day. The cost of thinning a tree, allowing two dollars a day for a man's wages, would be 64 cents. An expert thinner who could take off 1,000 apples an hour would cut this cost down to 48 cents per tree.

DOES THINNING PAY?

It often happens that the fruit grower does not like to do a thing unless he is sure that he will get quick returns for his labor. He so often does not look far enough into the future to regulate and manage certain factors over which he may have control that would insure future returns which would more than pay for any extra effort that he might put forth. From this standpoint it is necessary to consider other phases than that of the net returns of a single year, to tell whether or not thinning pays. These may be stated as follows:

1. Maintaining *the vigor of the trees. 2. Securing annual crops instead of alternate. 3. To be able to produce fruit of maximum size, color and quality.

Maintaining the Vigor.—This is a very important factor, for any fruit tree when injured or impaired in any manner, will not be able so successfully to resist insect, fungus and freezing effects. Thinning annually and uniformly will have much to do in preserving this vitality. Whenever the question is asked an orchardist, "Why is it that this apparently healthy apple tree is not bearing this year?" the chances are that he will answer, either that the fruit or bloom was killed by frost, or that it overbore the year before. It is noticeable, in this connection, that a tree with a heavy bloom will go through the average spring frost with little damage to the crop.

There is no doubt that the orchardist is right when he claims that overbearing one year will cause "shy" blooming the next with some varieties of apples, such as the Jonathan for instance, and the writer has seen the Ben Davis affected in the same way. The Winesap, as a rule, is not a "shy" bloomer, and overbearing may weaken the vitality, causing the tree to grow small, inferior apples, some of which never properly ripen.

The breaking down of limbs is the result of overbearing and can only be avoided by either propping or pruning and thinning. We firmly believe that props have no place in an orchard and when used are only a sign of very poor orchard management. There is no doubt that pruning has a very important place in orchard management and should not, by any means, be neglected. Especially is this true for the young trees. If a tree is properly pruned every year from the time it is set out, the amount of pruning can be decreased somewhat in proportion to the size of the tree when it has become full-grown. The word full-grown is used more or less arbitrarily, but generally conveys the idea that the tree is capable of bearing a full crop. Some think that every apple tree can be thinned

*E. R. Bennett, Storrs, Conn. Experiment Station Report, 1903.

enough with the pruning shears in the winter time, thereby doing away with the necessity of thinning by hand in the summer. These people forget that the plant food that goes to make and mature the apple is manufactured by the leaves and not by the roots of the tree. Keep a tree defoliated in the summer for any length of time and you will kill it. It is not best to obtain all of the leaf surface possible, as would be the case with an unpruned tree, for this would mean wood growth at the expense of fruit, and a greater amount of hand thinning. There would also be too much shade for the fruit and a poor color would be the result. A well balanced and well cared for tree, bearing a good crop of uniform sized apples every year will retain its vigor, while a tree allowed to bear an enormous crop one year and none the next may suffer the consequences of over production.

Securing Annual Crops Instead of Alternate.—A tree will produce quantity at the expense of quality, and at the same time utilize plant food that should be used in making the fruit buds for the next year's bloom. The law of nature is to reproduce its kind and it tends to do it even at the expense of the welfare of the tree. Annual thinning tends to throw a tree into annual bearing. When a tree has been in the habit of bearing alternate crops, it may take some time to induce it to bear every year by thinning. It has been demonstrated in the orchard where this experiment was carried on that by annual thinning the Jonathan can be made to bloom well every year.

Fruit of Maximum Size, Color and Quality.—The total averages, as given in the table found in the different grades, illustrates the points of size and color, for apples have to be of a certain size and a certain color to be packed in the first two grades. The following table illustrates the comparative values of the different grades. The culls were selling at the cannery and evaporator at \$7 per ton, or the equal of \$0.175 per fifty-pound box.

	Ex. F. Boxes at \$1.75	Ex. C. Boxes at \$1.50	Stand. Boxes at \$0 85	Cull Boxes at \$0.175	Cost of Thinning
Thinned	5.34=\$9.35	3.07=\$4.61	3.2 =\$2.72	1.11=\$0.19	\$0.64
Unthinned	2.5 =\$4.38	1 =\$1.50	9 =\$7.65	5.08=\$0.89	....
Thinned	Gain=\$4.97	Gain=\$3.11	Loss=\$4.93	Loss=\$0.70	Loss=\$0.64
\$8 08—\$6 23=\$1.85, total gain per tree.					

When trees are set 16x32 feet, there are 85 to the acre. A gain of \$1.85 per tree would make a total gain of \$157.25 to the acre.

This seems strong evidence that thinning the Winesap gives large returns for time and labor expended. The above figures are conservative in at least two respects: 1st. Many of the windfalls which were counted as culls could never have been sold for any purpose; especially was this true of the early dropped windfalls. Also there is much doubt as to whether the amount received for the culls would have paid for the extra labor required in picking, hauling and sorting. 2nd. The extra amount of time that it took to grade the apples from the unthinned trees for packing was considerable. These two expenses would alone almost offset the cost of thinning.

Uniformity of size was very characteristic of the apples from the thinned trees, while the apples from the unthinned ones were of all sizes. (See Fig. 1.)

Better colored fruit was always found on the thinned trees than on the unthinned, due largely to the fact that the fruit on the unthinned trees was crowded and consequently more or less shaded.

The lessened percentage of wormy apples, due to picking and destroying the apples infested by the first brood of worms, would probably be a saving sufficient to largely bear the expense of thinning.

HOW TO THIN.

Study each tree individually and thin so that at picking time the tree will hold up well under a load of uniform, good sized and well colored apples. It takes experience and study to get the very best results from thinning.

The experiment indicates that best results in thinning the Winesap can be attained when the apples are thinned to a distance of from nine to ten inches. It is well to commence at the top of the tree and work down. Perhaps, if there is any difference in distance to be made, it would be better to thin the apples on the lower limbs next to the trunk of the tree a little farther apart on account of there being more shade in this part of a tree. Although some shade is a good thing, as it prevents sun-scalded fruit, it is possible to have too much.

A very good type of thinning shears is shown on the front cover page. Thinning is much more easily done with this instrument than by hand. (Fig. 2 shows how a small branch with a heavy load should be thinned.)

Take off all terminal apples on long, slender branches and break all doubles. Take off all wormy apples and all those that are much smaller than the average. Take off all limb-bruised or badly frost marked apples, and also those that are liable to become limb-bruised as they grow in size. Leave the apples in singles and in

such a position that they can have the best chance to grow in size, color and uniformity, and be as free as possible from blemish.

There is another phase of thinning that would help, and that is the cutting out of every other tree in rows that have the trees so close together that they are crowding each other. Trees, when crowded, are bound to grow upward rather than outward, and if left alone will, in a little while, have most of their fruit bearing wood in the tops. This is truer of peaches, perhaps, than of apples, nevertheless apple trees when crowded cannot do as well as

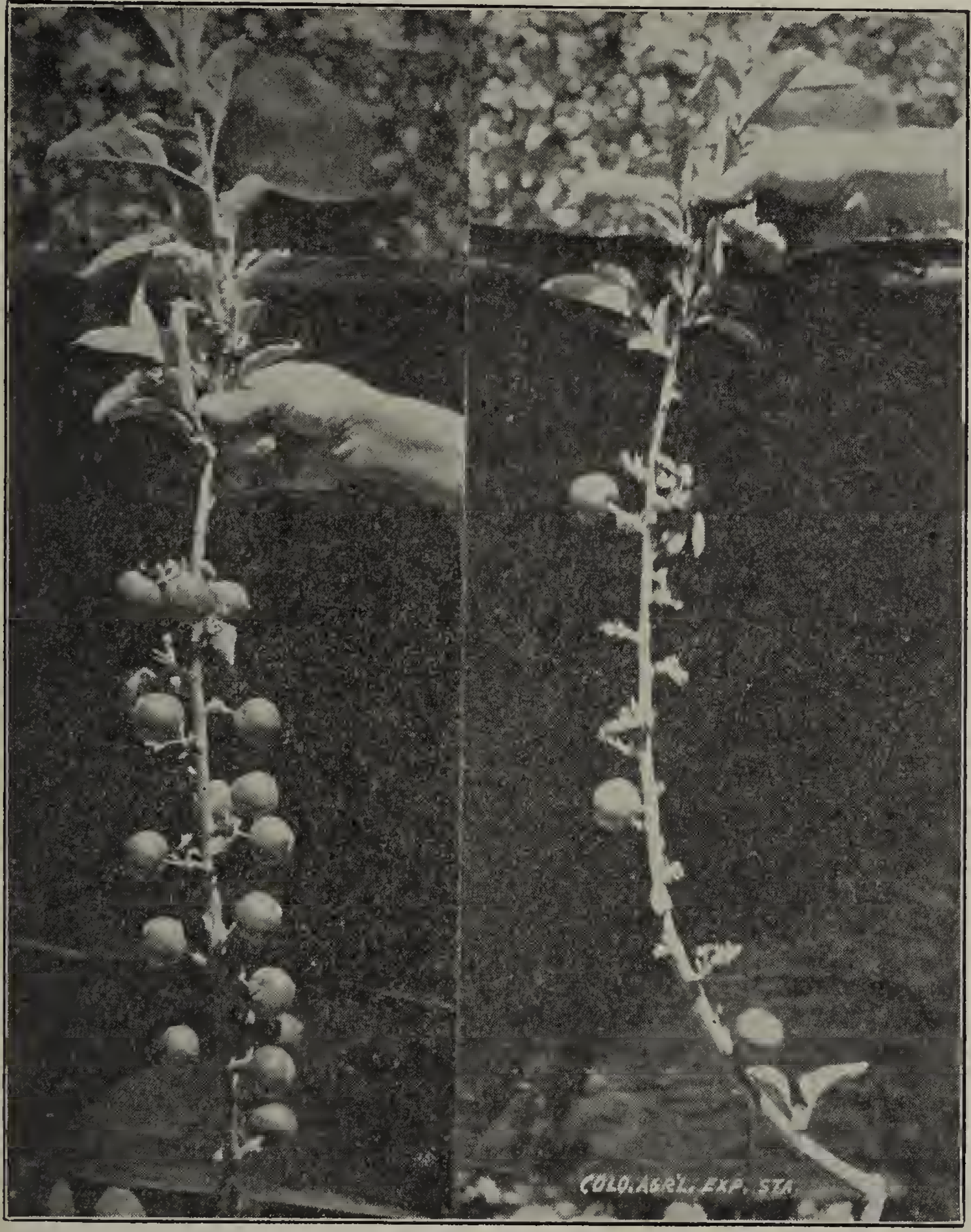

Figure 2. A three-foot branch before and after thinning.

when they have plenty of room. For this reason it is necessary to cut out every other tree in the row, or the alternates in every row, this depending on the way and the distance the trees are set.

CONCLUSIONS.

1. That thinning of the mature Winesap tree pays in money returns the first year.

2. The more evenly distributed the fruit on the tree the more uniform will be the size and color of the pack.

3. That Winesaps respond to thinning by increased size and better color when thinned as late as July 20.

4. The earlier that thinning can be done. the better will be the returns from the fruit sold and the greater will be the vitality of the tree.

5. The best results are attained in thinning an old Winesap tree, by leaving the apples from 9 to 10 inches apart.

6. That proper pruning, and keeping the trees a proper distance from each other will facilitate thinning.

7. That systematic, annual, uniform thinning done from the time the trees come into bearing, should have much to do in securing an annual crop, thereby doing away with the so-called "off year" bearing of some of the apple varieties.

WINTER AND FROST INJURIES OF FRUIT TREES

The object of the following discussion is to define as nearly as possible the different effects of freezing temperatures upon fruit trees and also to show that these effects often cause the death of fruit trees in Colorado. The subject divides itself into the following heads, namely: winter injury of young trees; winter injury of old trees; and spring frost injuries. In this bulletin, injury to peach and apple trees only will be discussed.

WINTER INJURY OF YOUNG TREES.

This divides itself into two heads, injury done to young apple trees, and that done to young peach trees. Young apple trees are injured for the most part, by freezing at the ground line, and by sun scalding on the trunks. Injury to young apple trees at the ground line is often caused by very low temperatures, resulting in perpendicular cracks which extend on the trunk from the ground line, or just below, upwards to a distance of an inch, or sometimes more. There may be from one to five cracks depending upon the severity of the freeze. In some varieties, such as the Rome Beauty for instance, it is often found that the bark bridges up between these cracks, causing a complete girdling of the trees, which often kills the tree. In most varieties, such as Jonathan and Winesap, the tree generally has strength enough to heal these wounds over so that in a few years they are hardly noticeable. In those cases where there is danger of killing the tree, it would be a good thing to fill the cracks with wax, or it might be of value to heap damp earth around the base of such a tree. If very bad cracks (Fig. 1) were found and taken in time, it might be possible to save the tree by bridge grafting.

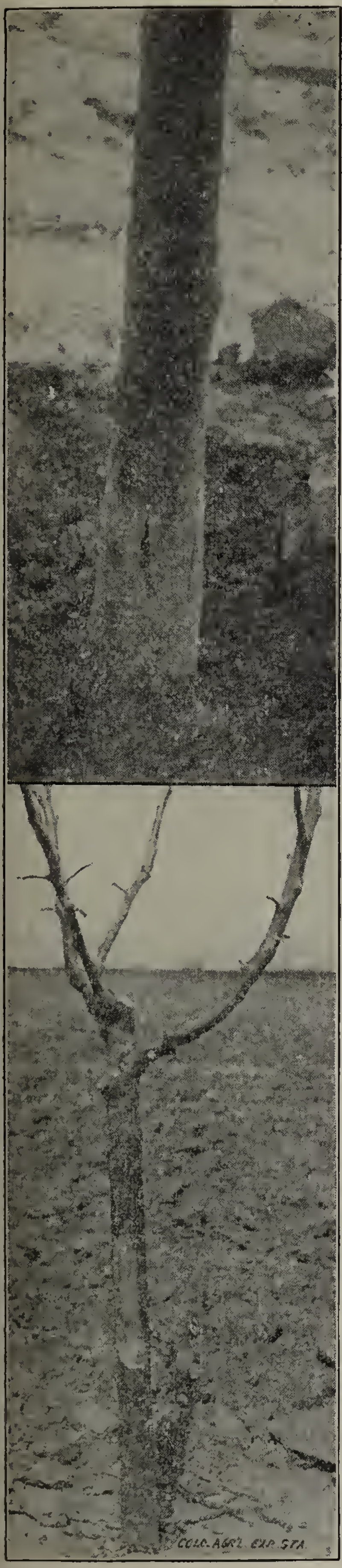

FIG. 1. Cracks at base of Rome Beauty caused by winter freezing.
FIG. 2. Winter injury by sun scald on southwest side of Winesap. The affected portion is cut out

In Fig. 2 there will be seen a case of sun scald. This sun scald generally takes place on the southwest side of the tree and, if severe enough, will work around, completely girdling the tree. On young apple trees sun scald is more frequent in winter than it is in summer. Especially is this true when the ground is covered with snow so that the sun's rays are reflected onto the trunks. It is very likely that sunny days and freezing temperatures at night have much to do with sun scald. The injury takes place, as a rule, from the snow line up to the scaffold limbs. In some cases it will be found to extend up on the scaffold limbs, but this latter condition is not so frequent. Prevention of sun scald is better than any remedy that could be prescribed for the trouble, although in severe cases it may be well to bridge graft. Whenever it is possible, it is better to use other methods than bridge grafting in Colorado, as our climate is so dry that it is very hard to keep the scions from drying out. Especially is this true when scions of any length have to be used. The fact that, as a rule, but little sun scald bark is found on the scaffold limbs, is one reason at least why low headed trees are practical. If by some method the ground could be left in such shape in the fall of the year as to prevent snow from lying in a level plane for any length of time, it might do much toward preventing sun scald of young trees. In localities where it is quite sure that the snow fall will be great enough to insure plenty of moisture, it might be well to leave the plowed ground in the fall in a rough state. This would do much to break the snow line. If a green shade crop were plowed under in the fall, this would help in the same way. In those places where the young orchards are bothered by rabbits, a wire netting extending from the ground line to

the scaffold limbs of the tree would not only keep rabbits from gnawing, but would also do much toward breaking the direct and reflected sun rays on the trunks. Wood veneering will answer the same purpose here as wire netting. Never use tar paper, as it not only concentrates the rays of the sun, but has an injurious effect upon the trunks, and in some cases the writer has seen death caused by its use.

It seems that the darker the bark the more liable it is to injuries from sun scald. Whitewashing the trunks of the trees is a very good practice and one that can be used on old trees as well as young. A very good whitewash is the California formula, which is as follows:

Quicklime	30 pounds
Tallow	4 pounds
Salt	5 pounds
Water	enough to make mixture flow well

Prof. W. Paddock says that this makes a tenacious whitewash not easily washed off by rains or removed by other means.

If whitewash is to be applied to the trunks of old trees in the winter time, it is a good thing first to remove all the old, rough bark. In this way many of the injurious insects that are hibernating over winter under this bark will be killed. A rough rasp or file is a very good implement to use in removing the old bark.

In peach orchard districts, where the temperature sometimes falls from 15 to 24 degrees below zero, there is more or less danger of damage being done to peach trees. Especially is this true when the trees are young and the temperature remains low for any length of time. It is sometimes very hard to tell whether considerable damage has been done to trees or not, until late winter, or sometimes it is the first of May before one can be sure whether the trees have withstood the rigorous weather. Perhaps, for peaches, the most common injury is that of killing the fruit buds. But this is not to be dreaded as much as freezing at the crown or ground line, which causes the so-called "collar girdle." Another form of freezing is that beginning at the terminals on the one-year wood and freezing back onto the older wood. This latter form is perhaps more common on older trees than young ones.

For the reason that it is almost impossible to tell the extent of the damage done by freezing until early summer, it is often a good plan to delay pruning until about the first of May. It must be understood that this is when the trees have undergone a severe winter. In other cases perhaps it is better to prune when a tree is dormant, although this is disputed by some of our best orchardists. At

rate, when severe freezing of the wood has taken place, it is
l to wait until the buds have started so that one will know where
prune. Even then peach trees may be so injured as to live
nths, or in some cases a year or two before dying from the ef-
:s of freezing. The so-called "collar girdle" seems to be one
t does not show until some time after the freezing has taken
ce. Trees injured by freezing very often need to be severely cut
:k. A peach tree will stand a heavier heading back than the apple
l for this reason can be pruned very severely, so that it will have
hance to put forth a new growth which, when properly pruned,
ı take the place of the old head.

One of the very important things to watch in connection with
:h young apple and peach trees is that of irrigation. It is a very
ɔd plan to get all of the growth possible during the early part of
: growing season, so that the trees may have a chance to harden
during late summer. In order to do this a young orchard should
ver be irrigated later than the first of August, and in many cases
would be better if the last summer irrigation took place not later
ın July 15th, the time varying somewhat with location, kind of
l, etc. Then, if no moisture comes in the latter part of October
first of November, it is a good thing to irrigate. If the trees are
t properly ripened or hardened off there is much danger that they
ll be killed back more or less by the first fall freeze. The writer
s seen cases of young peach trees where the terminals were killed
ck for several inches as early as the middle of October. This was
an orchard where the irrigation was kept up until some time in
ptember. The orchardist's object was to mature a crop of corn
at he was raising between the peach tree rows. By spring every
ach tree in this orchard was killed to the ground. It often hap-
:ns that a peach tree has enough vitality and plant food in the
unk and limbs to leaf out and may even bloom, and at the same
ne it may be so injured by freezing as to be girdled somewhere
ı the trunk so that in a little while the whole tree dies.

In the case of young apple trees, where the top is frozen back
the trunk, or where the trunk is injured by sun scald and freez-
g, it is sometimes possible to insert a scion by the cleft or kerf
ethod and thus growing a new top. In top working of this kind
: sure that the top is cut off below the injured portion, *i. e.*, have
ıe stock of good, sound wood. It is often possible to top work a
ɔung tree in this manner so that a single year's growth would al-
ıost equal that which was killed. In a case like this, where a tree
as a well established root system, it does not take long to form a
ood top, but one must be careful about letting it grow too late in
ıe season, as growth like this takes more time to harden off than
hen slower growth is made. In young trees which have under-

gone severe winters, it is often possible to find the sap wood (colored, generally due to freezing and in some cases traceable the annual rings to the year of the injury.

WINTER INJURY OF THE OLD TREES.

One form of freezing found on the old, and sometimes you apple trees, is due to "freezing dry." This is thought to res from perhaps two causes. one being lack of moisture in the s and the other a deeply frozen condition, stopping all root acti

Transpiration, or the loss of water from the limbs and twigs the tree, goes on in winter as well as in summer. Whenever eit or both of the conditions mentioned above exist for any length time, the results are detrimental to the tree and, if severe enou may cause death. For this reason it is necessary to irrigate in l fall or early winter. As a rule, the first of November is a desira time to do this, as it very seldom happens that the soil around t roots freezes enough to do any damage unless the trees are shall rooted. In this case root freezing might prove to be detriment. The above statements will hold for the peach as well as for t apple.

There is another form of winter injury to old apple trees th is often found and which, in some cases, is hard to distinguish fro injuries due to arsenical poisoning. The distinguishing featu are that the injury for the most part is at the crown or ground li primarily and seldom runs down into the root system. The roo of course, may be affected from this injury, but in such cases t injury would be secondary. The injury takes place in the form a partial or complete girdling at the ground line. The bark pe off in rough pieces and generally in one spot only. It may exte up to the trunk of the tree for several inches. It depends upon t size of this affected spot whether the injury will prove fatal to t tree or not. In cases of arsenical poisoning the bark becomes co roded to a mealy mass in which the tissues are broken down a may be scraped off from the wood, while with winter injury t bark remains intact and separates at the cambium. The writer h seen cases where fifteen year old Ben Davis trees were killed b this crown line injury. Attempts were made to save the trees b bridge grafting, but as stated before, the scions that had to be us were too long, and dried out before adhesion could take plac These trees were in such a position that undoubtedly more or le ice and snow remained around the bases of them for long perio of time. Although in some cases it would appear that ice arou the base of a tree had no detrimental effect, it is not well to allo this, as one can never tell when the conditions are just right f damage to be done. In the fall irrigation it is well to keep t

er in the irrigation furrows and not let it collect around the s of the trees and freeze. Perhaps there is no harm in allow- it to freeze in the furrow.

The worst injury to old peach trees, other than that of killing n outright, is that of killing the fruit buds. For this reason it good plan to delay pruning until one is sure what buds are e and what are dead. But if this is kept up for any number of s the chances are that the fruit bearing wood will be in the top he tree and will eventually necessitate a severe heading in.

SPRING FROST INJURIES.

Perhaps there is no injury due to freezing temperatures which s such immediate results as that of killing frosts in the spring. s too, may have its effect throughout the growing season, but primary effect is that of a total or partial killing of the bloom, sometimes that of the set fruit, in the spring. It is not the object his bulletin to discuss the protection of the orchard from frost. ept in a general way.

Some Effects of Frost on the Fruit and Leaves.—Frost may evere enough to cause only a partial failure of a crop, and when is the case there is always more or less of the injury seen ughout the season. The most common of these are frost marks sisting of russety patches at both the stem and blossom ends, or ome cases russet bands around the fruit. These russet bands often seen on the pear. One form of injury, thought to be due reezing, not often seen, is that of small round russet spots on surface, which may be in almost any position on the fruit. This been seen on the Northwest Greening and was supposed at t to be due to spray injury, but upon investigation it was thought e due to frost injury when the apples were small. It often hap- s that apples and pears are so injured as to have no seed. An- er form of injury to the fruit is that of freezing a part or all the calyx end, causing the fruit to be deformed. In this latter e the injury generally takes place after the fruit has been poi- ted and has set.

The early leaves are often injured by frost and the effects are t they never grow much larger in size than they were at the time freezing. They may turn yellow and drop during the early sea- , or they may still hang to the trees, but if they do, they become ch thickened, somewhat shriveled, and turn yellow much quicker n the uninjured leaves. As a rule, if the frost is not too late, damage done to the leaves is not enough to cause any alarm. some severe cases where most of the leaves are out and all are ured to such an extent as to cause them to drop, there might be ne detrimental effects. But, as a rule, the tree will soon throw

out new leaves which will take the place of the injured ones

Prevention of Frost Injuries in General.—As this is a subj that would require a bulletin to be satisfactorily handled, we w give only some of the most important features concerning orcha heating. The following conclusions were drawn after consulti over forty of the leading orchardists of the State who had us orchard heaters:

1. The fact that every orchardist, who had been interview upon this subject, claimed that the orchard heater is a good inve ment as an assurance in the fighting of frost, indicates that t orchard heater has come to stay.

2. The oil heater is usually preferred over the coal, wh more than five acres are to be heated, because of its more econo ical maintenance.

3. On cold, windy nights orchards with low headed tr receive more benefit from the heaters than high headed ones.

4. Good thermometers well tested should be in the orcha as well as on the outside.

5. Careful study of the stage of growth of the fruit bu should be made to ascertain their hardihood against frost injuri.

In regard to the stage of growth of the fruit buds, bloom a set fruit of peaches and apples, as compared to their resistance frost, the following opinions are given: Prof. W. L. Howa *states that in Missouri fully dormant peach buds can stand 8 9 degrees below zero. When appreciably swollen, zero is the da ger point. When the buds are showing the pink, they can stand degrees above zero. When the petals are off they stand 30 degre above zero. For apples, when the petals begin to show, they c possibly stand a temperature of from 20 to 22 degrees above ze From this stage on their resistance to cold becomes less and less growth progresses.

Prof. P. J. O'Gara †states that, in the Pacific Northwe, peaches in bud are injured by a temperature of 29 degrees F.; i blossom by 30 degrees, and set fruit by 30 degree F. Apples i bud are injured by a temperature of 27 degrees; in blossom by 2, and set fruit by 30 degrees F.

Prof. O. B. Whipple ‡found that it is doubtful if, in Colorad, a temperature of 30 degrees F. will injure fruit or buds, in a stage of growth. That a temperature of 28 degrees, if of lo enough duration to freeze the tissues solid, will kill peaches i

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*Reprint from the Annual Report of the Missouri State Board Horticulture, 1909.

†Farmers' Bulletin No. 401, U. S. Dept. Agr.

‡Fruit Growing in Arid Regions, by Paddock and Whipple. p. 35. The MacMillan Company.

bloom or after the peaches have set. That after the peaches have reached some size they will stand a lower temperature for a short period of time. Peach trees well loaded with buds which show slight traces of pink, have often escaped with a good crop with a minimum temperature of 22 degrees. Fruit buds of apple and pear open far enough to show the flower tips, are seriously injured by temperatures lower than 20 degrees. When they are far enough advanced to show the color at the tips, they are generally only slightly injured by temperatures as low as 25 degrees. When in bloom and after the fruit is set, they will seldom stand temperatures lower than 28 degrees. Cherries, apricots, and most of the plums, will require about the same protection as peaches. Native plums in bloom or with fruit set will often stand a temperature of 25 degrees.

It will be seen from the foregoing that the danger point in temperature varies for the different fruit sections and for the different kinds of fruit. It may also vary in the same locality for different years and several years' observations will be necessary in order to get full data on all the conditions that have to do with resistance of freezing temperatures.

Careful study of the weather conditions should be made when orchard heaters are used. Some money can be made in the saving of fuel by starting and putting out the fires at the proper time. Oil heaters when fired can be put out and relighted instantly, while coal is very hard to relight. A good plan is to commence lighting the heaters when a temperature of 30 degrees is reached. If the temperature can be kept at 29 degrees or above, as a rule, there will be little damage done to the bloom or set fruit. The writer has seen, with systematic handling of the heaters, a temperature of around 21 outside raised to 29 degrees in the orchard. It is thought there is no harm done to the trees in the spring from a small amount of oil spilled in the orchard, nor from the gases, soot, etc., which come from the coal and oil.

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The Colorado Raspberry Industry

BY

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AND

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A good type of Cuthbert raspberry bush.

THE COLORADO RASPBERRY INDUSTRY

By R. S. HERRICK AND E. R. BENNETT.

The raspberry is one of the best known small fruits. In its wild state it has been used as food since the beginning of history. This fruit belongs to the family of brambles of which there are many hundred species. The raspberries of commerce are mostly included in three species. These three species are divided between two quite distinct types, the reds and blacks.

The European red raspberry, *Rubus Idaeus,* is little grown in this country. The fruit is similar to the American red raspberry in appearance, of better quality, but the plants are less hardy. The early attempts at red raspberry culture in this country were largely confined to the development of this species but these have never succeeded because the species is not adapted to our climatic conditions.

The American red raspberry, *Rubus strigosus,* is of comparatively recent domestication. In the wild state it is found more or less over the northern and eastern United States. One variety of this species is native in the higher altitudes of the Rocky Mountains. This wild raspberry of the mountains is far superior in quality to the domesticated berry or to the wild berry of the East. Up to the present time however nothing has been done to improve or acclimate the berry to cultivated conditions.

The black raspberry, *Rubus occidentalis,* is also native to the northern and eastern United States. The black raspberry of commerce is practically the same as the wild berries of the fields. This species is commercially the most important of the raspberries.

Another species, *Rubus neglectus,* is a hybrid of the American red and black raspberry. This species is relatively unimportant. It is represented by what is known as the purple cane berries.

The raspberry has reached its greatest commercial importance in the northeastern states. This is because the fruit demands a cool climate and a loose, moist soil with an abundance of humus. In a wild state both the red and black varieties are found at their best on newly cleared timber lands of the eastern and central states. Land from which timber has been removed in the East is nearly always first occupied by the raspberry brambles. After the surface humus becomes more or less exhausted these bushes disappear.

The great drawback to raspberry growing either in a wild or cultivated state is the droughts that are apt to occur at time of ripening. For this reason the culture of this fruit has been to a great extent confined to those regions of sheltered timber lands and plenti-

ful rainfall. The red raspberry seems to be as much at home in the burned over timber lands of the high altitudes of Colorado as in Michigan; consequently we may conclude that the soils of Colorado are as well adapted as in the eastern states.

Comparatively few diseases attack the raspberry in the dry climate of Colorado. The yield and quality of fruit is equal or superior to that of the East.

Raspberry growing has become one of the important industries in several districts of Colorado and it gives promise of proving even more valuable in the future because the conditions for the best development of fruit may be more readily met on the irrigated lands of Colorado than in the uncertain climatic conditions of other parts of the country.

REQUIREMENTS.

Although the raspberry is one of our fruits that can be raised in most any section of the state up to an altitude of ten thousand feet and in various kinds of soil, there are certain requirements that, if followed, will insure its success.

Soils.—The native raspberry of the state is found on mountain sides where there is a good supply of humus. The cultivated plant is grown in soils ranging from a light sandy loam to a heavy clay. On investigation it has been found that the earlier fruit is on the sandier soils, but the better production comes from those plants growing in a heavier soil such as a clay loam. The sub-soil is an important matter as regards drainage. The best subsoil would be that of gravel or sand. With less impermeable sub-soils the site requires more slope to insure proper drainage. The depth of soil that is the best for raspberries is more or less an open question. Perhaps six or eight inches of good surface soil is deep enough for a short lived plantation. There is no doubt but that a soil two or more feet in depth is better for raspberries than a shallower one. The more humus that the soil contains at the time of planting the better will be the result in growth.

Climate.—The different climatic conditions which exist in the state necessitates two distinct methods of handling raspberries. In those sections where the temperature falls to several degrees below zero and remains there for any length of time it is necessary to cover for winter protection. In those sections where the temperature never falls to but around zero it is not necessary to cover either the red or black varieties. Then there are other sections where the red varieties have to be covered and the black do not need winter protection. As far as climate is concerned raspberries will stand the most rigorous

climatic conditions of any of our fruits, if covered for winter protection.

Moisture.—The raspberry requires a medium amount of moisture for its best growth except during the fruiting stage, at which time it requires a maximum amount. For the most part it is not practicable to raise raspberries in Colorado without irrigation. It might be possible to grow them in certain sections where the rainfall is plentiful as compared to the state's average rainfall but it is doubtful whether or not in those sections there would be moisture enough to insure proper growth during the fruiting season.

If one intends to go into the raspberry business it would be well to select a location where a favorable market could be had quite near at hand. Careful selection of the site is necessary as regards climatic conditions, depth and kind of soil, amount of moisture to be had, etc. A southern slope may be warmer during the winter but it may also dry out quicker, and this is quite an important factor for all fruits.

PREPARATION OF THE FUTURE RASPBERRY PLANTATION.

When a fruit plantation of any kind is to be planted on new land it is well at first to get it into the best possible condition. In order to insure the best results it is important that the seed bed be properly made before setting out the plants. Not infrequently fruits of various kinds are set in raw land that has never been plowed except in the rows where the plants were set. In such cases the plants often grow in a stunted way and never acquire the vigor that they should attain.

One of the best crops for growing on raw land is alfalfa. If alfalfa has made a good growth it may be plowed under the second fall and if the soil is poor in humus it would be well to plow under the last cutting. This will do much in bettering the physical condition of raw soil.

It is well to follow the alfalfa with a hoed crop of some kind, such as potatoes, corn, etc. This will help to do away with the weeds and leave the soil in fine condition for planting.

Another reason why land should be cropped before setting out raspberries is that when raw land is first irrigated it most always settles more or less in spots. As irrigation is necessary year after year, it is important that the land has the right slope and has a comparatively smooth surface. The writer knows of no way by which this can be accomplished better than by cropping the land, for two and in some cases four years before setting out fruit of any kind.

Fall plowing is preferable to spring plowing especially when there is a green crop to be plowed under. Earlier spring planting can also be done when the plowing is done in the fall. Irrigation just

before the fall plowing will put the land in a better state of moisture at planting time in the spring.

Plenty of barnyard manure will take the place of a green crop. Perhaps barnyard manure does more good if applied after the plants are set than when used before.

DISCUSSION OF VARIETIES.

Although different varieties are more or less localized there are places in Colorado where it is thought that most any kind of raspberry could be grown. In the Loveland district the Marlboro is grown more than any other variety. This is a red raspberry and requires winter protection by covering. At Canon City the black-cap is raised quite extensively. Gregg is the variety most used. Each of these species, that is, the red and black-cap have their advantages. The red raspberry as a rule brings a better price on the market than the black. The black-cap varieties hold up perhaps a little longer in shipment and in many parts of the state do not need winter protection. On the western slope of Colorado the black-cap, red, and the purple cane varieties are found. In some places on the western slope none of these kinds are protected during the winter but it is thought that for the best growth and welfare of the plantation, the red varieties should be covered.

The best red variety for Colorado is undoubtedly the Marlboro on account of its good shipping qualities. The Cuthbert is also a very good variety for home use as it has a better quality and flavor than the Marlboro. Its chief objection is that it is a rather soft berry and will not stand shipment for any great distance. With careful picking and packing the Marlboro will stand up from thirty-six to forty-eight hours depending somewhat on the temperature, while most of the other red varieties go down in from twelve to twenty-four hours. For evaporating purposes the black-caps are better than the red varieties on account of their hardiness. When used for this purpose they can be picked by mechanical means thus doing away with hand picking. So far in Colorado there has been such a demand for raspberries to be used as dessert that it has not been necessary to resort to evaporating. In fact, during the last year there were not enough raspberries raised in Colorado to supply the local market. The following is a list of the different varieties of raspberries which are known to do well in Colorado. The purple cane varieties, as a rule, are the best for canning purposes.

RED RASPBERRIES.

Only very brief descriptios are given of the following varieties of raspberries on accout of the lack of space; these are given in their order of importance.

Marlboro.—This variety is of only ordinary quality but noted for their firmness both on the bushes and hold up well in shipping.

Cuthbert.—A good berry for home use, having fine quality but generally too soft for shipping long distances.

Loudon.—Canes vigorous, quite hardy, and productive. A good berry for local market or home use.

Turner.—This variety is very hardy and vigorous. Fruit, sweet and of excellent flavor.

Golden Queen.—In all characteristics this is a Cuthbert except that it bears yellow fruit. A few for home use are desirable.

BLACK-CAP VARIETIES.

Gregg.—Best known late variety. Very good shipper and an excellent variety for evaporating when picked by hand.

Kansas.—Fruit similar to Gregg ripening a week earlier, juicy, of excellent flavor and firm enough to ship well.

Ohio.—The great evaporating raspberry of the present day. Quality poor as it is very seedy but yields more pounds of evaporated fruit per bushel than any other sorts.

PURPLE CANE VARIETIES.

Shaffer.—An excellent canning variety.

Philadelphia.—This represents the red raspberry more closely than some of the other purple cane varieties. Propogated by suckers, yields but sparingly.

Columbian.—This is of the Shaffer type and ripens a little later.

PROPAGATION.

Propagation of the raspberry varies according to which species it belongs. The red raspberries are propagated from the suckers which come up from the parent root. As a rule most of the red varieties throw up enough suckers to insure plenty of young plants. For this reason careful cultivation has to be resorted to in order to avoid injuring the root system of the old plant. For when it is injured it acts only as a stimulant to throw more shoots and often requires a severe pruning to keep them down. The old plant can be separated by division thus obtaining extra plants for planting purposes, but as a rule this is not as good a plan as to use the young shoots with the roots attached.

The black raspberry is propagated by tip layerage. This is done by covering the tips along the latter part of July or the first of August. They take root at this point and generally establish themselves well enough so that the next spring they can be separated from the parent stock by cutting the cane off near the ground.

The purple cane varieties vary somewhat in their mode of propagation according to the variety. The most of them however resemble the black-cap in this respect and are propagated by tip layerage.

SETTING PLANTS.

It is a good plan to grow the variety which has done the best in that locality. It is better to secure home grown plants when such are available rather than to use plants brought from a distance.

Age of Plants.—It is believed that yearling plants are the most desirable for the new plantation. By this we mean those plants which have grown one full season and not those that were started the summer before. In some cases it is perhaps possible to get good stocky plants which were started the summer before but generally these are small and spindling and have a poor root system.

Time of Setting.—In Colorado the best time to set raspberry plants is in the spring. This should be done just as early as is possible to avoid any damage from severe frosts. As a rule, the middle of April is a good time. For this reason it is well to have the land plowed the fall before.

Distances.—The distances that raspberry growers use in setting out new plantations vary somewhat according to variety and locality. In those localities where the winters are not severe enough to require laying down it is not necessary to plant the rows as far apart as where protection from the winter is required. Where protection is necessary the distance for the red raspberry between the rows is seven feet apart and in the row two feet and eight inches. The distance in the row can be greater than this providing the pin system of laying down is not used. This distance varies from that mentioned up to three and a half feet. In those localities where laying down is not required for winter protection, the distance of five to six feet for the rows and from three to five feet in the rows is used. This enables cultivation to take place both ways. It requires 2333 plants per acre when set two feet eight inches in the row and rows seven feet apart.

The black-cap varieties in those localities where winter protection is not used, should be planted with rows the same distance apart as for the red, that is, about seven feet and about five feet in the row. Where covering of the black-cap is necessary it is better to have them a little closer than this, from three and a half to four feet. This latter distance will require severe pruning of the plants to keep them from forming a hedge row. The purple cane varieties can be the same distances as the black-cap which in habit they so closely resemble.

Method of Setting.—A good method of planting is to have the rows staked off the desired distance from each other and plow a deep furrow where the rows are to be set. Set the plants by hand the de-

sired distance in the row from each other and place some dirt around the roots of each to keep them from drying out. The rest of the dirt can be plowed back with one horse. Irrigation should follow as soon as the plants are set in order to keep them from drying out. If cultivation is to be done both ways it would be well to set the plants in check rows. This would lighten the expense of cultivation especially for large areas.

CULTIVATION AND IRRIGATION.

In those localities where covering is necessary for winter protection there is less need perhaps for an annual plowing as this is done in the fall when covering and in the spring when uncovering. This keeps the soil from forming a hard pan four or five inches below the surface as is often found when only clean cultivation is used. A good rule to follow during the summer is to cultivate after each irrigation except during the fruiting season. This will not only prevent the ground from baking but will often take the place of irrigation. During the fruiting season it is necessary to irrigate some soils almost every other day; for others twice a week is plenty. It is probable that if careful irrigation and cultivation were used during the growing season, it would not be necessary to irrigate so often during the fruiting season. Over irrigation has a tendency to soften the fruit. In running the water between the rows it is not a good plan to have the irrigation furrows too near the plants, as it is hard to cultivate the furrows in when they are too close.

There is a dispute as to whether the plantation should be irrigated and cultivated up to the last of the growing season or whether it is better to allow irrigation and cultivation to cease about the first of August, thus giving the plants a chance to ripen. It is thought that this latter practice is the better. Irrigation can be done the latter part of October or the first part of November. This will enable the plantation to be more easily covered with soil. This late irrigation is also beneficial in keeping the soil moist during the winter.

Cultivation is quite necessary during the growing season to keep down weeds and perhaps more important to keep down suckers in those varieties that are inclined to throw up a great many shoots. Square teeth are used on the cultivator in the place of the round ones in order to cut the shoots off just below the ground. These square teeth can be made by any blacksmith and are one of the best implements to use to keep down suckers. It cannot be emphasized too much that irrigation cannot take the place of cultivation. But on the other hand, it is often possible for cultivation to take the place of irrigation with good results. Frequent hoeing during the season up to the fruiting period is necessary especially where the plants are

not check rowed in order to keep weeds and raspberry shoots from growing in between the hills. It is always better to keep thrifty hills in the row rather than to let them grow together and form a matted row.

WINTER PROTECTION.

As has been stated before it depends largely upon variety and locality whether or not it is necessary to lay the plants down for winter protection. In the Loveland district all varieties are laid down. In the Canon City district and most places on the Western slope the black-caps are hardy and do not need winter protection, while the red raspberries as a rule are covered.

Methods of Protection.—There are two principal methods used by which raspberries can be protected from the winter freezing, namely, that of covering with straw, leaves, etc. and that of covering with earth. As a rule in Colorado the earth covering is the more practical as straw and other material is sometimes scarce.

Raspberries are laid down from the middle of October to the middle of November, depending somewhat on the weather conditions. There are two principal systems used in laying down the plants, namely, first that of pinning, and second that of bending over and throwing dirt on the tips, thus holding them down. The pinning system is done by commencing at the end of the row and pulling the first two hills down so that the tops of each are at the side of the base of the other. They are held in place by pieces of old canes which are broken to about six inches in length and so placed as to hold the canes in a firm position on the right hand side of the base of the plant. In order to do this pinning properly it is necessary to either have canes long enough to overlap when they are laid down or have the hills close enough together. It is always well to have the tops of one plant at the right of the base of the next and to keep this up throughout covering. If this is done uncovering in the spring can be aided by using a right hand plow, to plow at least one furrow away from each row. Another form of holding the plants down until some earth can be placed upon them is that of using a six tined pitch fork and holding the tops in place until earth can be shoveled onto them. By using either the pinning or fork system of holding plants in place, one man can very easily cover his own canes. Placing soil upon the canes to hold them down takes from two to three men. One man bends the canes down and the other two shovel soil upon them. In pulling the canes down into place it is necessary that they lay quite flat on the ground in order to be properly covered, otherwise they are apt to loop in the center causing an air space and the likelihood of their becoming uncovered before spring. See Fig. 1.

Figure 1. Raspberries not properly laid down and covered.

One of the vital phases in the protection of raspberries is that of uncovering in the spring. If uncovered too early they may be caught by late spring frosts and on the other hand, if uncovered late, the buds shoot out into white tender growth which may be killed by hot winds. A good plan would be to commence uncovering to within about one-half an inch of the canes, about the middle of April and to keep this up gradually for some time until the work was completed. This would give a chance for the young growth to harden off so as to resist the change of climatic conditions.

The labor of covering the canes may be facilitated by plowing two furrows on each side of the row before using the shovel. It is a good plan to have a well rounded ridge with plenty of earth on either side to form rather wide bases. This will help to keep the earth from falling off from the top as would be the case with a narrow high ridge. Fig. 2. is an example of well covered rows.

In uncovering the plants in the spring never allow any soil to pile up in the hills or between them, for, if this is allowed it will not be

Figure 2. Raspberries well covered. Note the wide ridges which help to prevent the soil from rolling off of the sides and tops.

long before the rows will be growing on ridges. In order to keep this soil from forming into ridges it is necessary to remove it with a hand hoe from between the hills.

PRUNING.

Perhaps no one thing has as much to do with the life of the raspberry plantation as that of pruning:

Pruning for Red Raspberry.—It is a good plan to prune out all old canes just after the fruiting season and the following fall cut the main canes from three and one half to four feet in length and also remove any small inferior ones. It is, as a rule, better to leave more canes in the fall than you really need. The next spring when the canes are uncovered take out all canes that have been injured or broken and leave only the better ones in each hill. The number to leave depends on the vitality, etc. of the plants. This can best be determined by practice. As a rule, eight to fifteen canes are enough, when properly selected, for each hill. Where red raspberries go through the winter without covering they should be treated the same as black-caps. But it is thought for most districts of Colorado it would be better to

cover and prune as above stated. Mid-summer nipping of red raspberries causes laterals to be thrown out. As a rule this is not a good practice as these laterals are often broken in covering and uncovering. It is better for the fruiting cane to throw out its lateral in the early summer after it has been uncovered. The figure on the front page is a good type of pruning knife for cutting out the old canes.

Pruning of the Black-Caps.—Where the black-cap raspberry does not have to be covered for winter protection the following method should be followed. Cut out all old canes after the fruiting season and at the same time pinch back within three feet of the ground all new canes allowing these to throw out new laterals. In some cases it may be necessary to do this pinching back of new canes before the fruiting season. In this case another pruning is required. It is well to do this before the canes have grown too long. They shoud be pinched back to from eighteen to thirty-six inches from the ground. In the spring go over each hill cutting out all diseaseed or broken canes. Where black-caps have to be laid down for winter protection they can be treated the same as red raspberries as regards pruning.

The true purple cane varieties can be treated about the same as the black-caps which they more closely resemble in habit.

GENERAL MANAGEMENT.

The question is often asked, "Can raspberries be raised successfully in a young orchard?" This depends somewhat on kind of soil and method practiced. It is believed that with a rich, deep soil and with proper management two rows of raspberries, or in some cases three, depending upon the distance the trees are planted, can be raised in a young orchard for four or five years, or until the trees require a great amount of spraying, etc. Never plant raspberries in the tree row as is shown in Fig. 1. In raising anything in an orchard it must be remembered that the trees are primary and everything else secondary. Raspberries require more water than young fruit trees but it is thought that by keeping the water from the trees and watering the raspberries only for a few years, at least, no damage would result from this practice. Fig. 3. shows a raspberry plantation growing between old apple trees. It shows the stunted effect on the raspberries of over shade and crowding.

Fertilizing.—The best way to fertilize a raspberry plantation is to haul manure during the winter in between the covered rows. This manure can often be of a rough nature and in some cases it is thought to be better than when it is fine and well rotted. Perhaps the reason for this is that its physical nature is more valuable than fine manure. When this is placed in between the rows it is covered the next spring by uncovering the hills. In this condition it soon decays and becomes incorporated with the soil.

Figure 3. Raspberries growing in a fifteen year old apple orchard. Note stunted effect on the raspberries next to the trees.

Life of Plantation.—Eastern authorities claim that the best results are obtained when the plantation is not allowed to grow longer than six or seven years. In Colorado it is thought that with the proper management and care a raspberry plantation will last from twelve to fifteen years. There are in the Loveland district at the present time plantations twelve years old and these seem to be as thrifty as younger ones. It is hard to give the life of a plantation as this depends largely upon the care given it.

YIELDS.

Yields for the raspberry plantation vary somewhat from year to year, it depends largely on the vigor and growth of the plant. An average yield for the black-cap raspberry is two hundred and seventy crates per acre; that of the red varieties is about three hundred seventy-five crates per acre. When we speak of crates we mean those which contain twenty-four pint boxes. In some cases the black raspberries are crated in quart boxes but unless for local market it is better to place them in pint boxes as the raspberries will hold up better. As a rule

the raspberry plantation will not come into bearing to any great extent until the third season.

HARVESTING.

Unless raspberries are picked for evaporating purposes they are picked direct from the bushes into pint boxes; these are placed in a hand carrier which holds six boxes and carried direct to the packing house. It has been found that carriers holding not more than six boxes are better than those holding more on account of their not allowing the berries to remain in the sun for any length of time. After the berries are picked they should be kept as cool as possible until marketed.

Markets.—When a good price can be obtained it is better to sell at a local market than to ship. Good markets for the berries grown on the western slope are found in the nearby mountain towns. In fact during the past year there were not enough berries grown to supply many of the local markets of the western slope. The berries of the Loveland district are handled by an association which finds various markets of which Denver is the principal one. Some berries are shipped out of the state.

Values.—The amount received per crate varies somewhat according to amount grown and place of market. The average cost for the made up crate is about fifteen cents each. The cost for picking and carrying to packing house is about thirty cents a crate. The gross value received for an acre of red raspberries for the average year would run from four to six hundred dollars. The average expense, including cultivation, irrigation, pruning, covering, picking and packing is from one hundred twenty-five to one hundred fifty dollars per acre. This would leave a net gain of two hundred fifty to four hundred seventy-five dollars for red raspberries and two hundred to three hundred fifty for black-caps per acre.

POSSIBILITIES OF THE INDUSTRY.

There is no doubt but that more raspberries could be grown in those localities where they are already growing and still have good markets. It is believed that there is a large field open for raspberries that can be evaporated. There is no doubt that raspberry growing properly managed can be made to be a paying proposition. There is no reason why every farm should not have a few well cared for bushes in its home garden. As has been stated before, raspberries will grow on a variety of soils and at various altitudes. Of course it might not be profitable to raise them on a large scale as above stated, but there is no reason why a few could not be raised for home use. With good railroad facilities and proper air cooled cars, raspberries can be shipped long distances. Properly air cooled cars are better for raspberries than ice cooled ones as raspberries when ice cooled soon go down when put on the market.

DISEASES.*

Raspberries in Colorado are not troubled with many fungus diseases, for the reason that the climate is too dry for the spread of such troubles as affect the canes above ground.

ANTHRACNOSE.

This can be detected by gray discolored spots found on the canes above ground. When these spots become very numerous they may cause death or greatly weaken the plant. The disease is a surface one, namely, it lives on and in the bark.

Treatment.—Affected old wood should be removed and burned as soon as the fruiting season is over. In setting out new plantations careful inspection of the plants should be made to avoid any with diseased canes. Spraying may be done with one-half strength Bordeaux or self-boiled lime sulfur. In this case it must be remembered that the mycelium lives over winter in the canes, and that spraying can only prevent the germination of spores as they are produced. Black raspberries are perhaps more susceptible to the trouble than the red varieties.

ORANGE RUST.

This disease is detected by the orange-red color on the under side of the leaves. This discoloration is due to the abundance of sori, which produce the orange-red spores by means of which the disease is spread from plant to plant. The mycelium of the fungus which corresponds to the roots of higher plants lives through the winter on the canes and roots of the raspberry. For this reason spraying is not very beneficial for its control. This disease is found more often on blackberries than on raspberries. Black raspberries are more susceptible to it than the red varieties.

Treatment.—All diseased plants as soon as discovered should be dug up and burned.

CROWN GALL.

This disease, caused by bacteria, is characterized by a rough knotty growth around the base or on the roots of the plant.

The most satisfactory treatment for this trouble is to avoid planting any diseased stock. When found in the plantation take out diseased plants and destroy.

CANE BLIGHT.

This disease has been thought for many years to have been winter injury. It is now thought to be a fungus trouble and is being worked on by Prof. W. G. Sackett of this station.

*The accounts of these diseases are taken largely from Card's "Bush Fruits."

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GARDEN NOTES, 1910

By E. R. BENNETT

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GARDEN NOTES, 1910

By E. R. BENNETT

The garden proposition in Colorado, differs materially from that in the East. It is always a question in a new country as to what will succeed, and what fail. Many people have thought that because of the high altitude of Colorado, few of the garden crops that succeed in the East could be grown here. In fact this idea has been so prevalent that for years many of the ranchmen in the higher altitudes of the State, have lived on canned goods and have freighted potatoes from distant points at four cents per pound, when vegetables, (potatoes in particular), could have been grown better on their ranches than in most places in the East, or even in the lower altitudes of Colorado. Different places in Colorado differ so materially in altitude, and therefore in temperature and rainfall, that it is impossible for anyone to give definite directions, or make definite statements as to what may be done in the State as a whole. Even when certain truck crops have been failures in many places, we cannot conclude that the crop may not grow satisfactorily in a given place until we have tried all the methods possible for its culture. In other words, because a given crop will not grow as handled in Iowa or Ohio, it does not necessarily follow that it cannot be grown, even more successfully, here than there, when we know how to adapt the culture of the plant to our conditions. Many strange discoveries have been made in the State along these lines. For instance, it has been found that cauliflower, cabbage and potatoes may reach the acme of productiveness and quality in places where it was thought almost no crops of these kinds could be grown. Because of these peculiar conditions, it has been thought best, particularly for the benefit of new comers in the State, to discuss the possibilities of growing the various garden crops and the methods which we believe to be best adapted to our conditions. It must be remembered that the work done along these lines, at this Station, cannot be taken as a guide, other than in a general way for similar work in other parts of the State. Almost no two places have the same conditions, and methods employed must be changed accordingly.

During the season of 1910, as many as possible of the annual truck crops adapted to Colorado conditions, have been grown in the gardens of the State Agricultural Experiment Station.

In the work of truck gardening, that has been taken up at the Experiment Station, two ideas are being kept in mind. First the truck crop from a commercial standpoint is considered. This includes all the crops such as cabbage, cauliflower, celery and the like, that are grown for local markets, and also for shipping to

distant markets. These crops are adapted to certain districts and from a commercial standpoint are not adapted to all districts. On the other hand, the truck crops for the home garden may be grown in practically all parts of the State, even though certain ones are not sufficiently adapted to the conditions to produce a maximum of yield and quality. For this reason, we will take up the various vegetables that are in any way adapted to our climate in the alphabetical order, as a matter of convenience, rather than in the order of their importance.

Asparagus.—Asparagus, is one of the most satisfactory crops for the gardens of Colorado. There are comparatively few troubles or pests that interfere with growing this crop in the home garden. In fact, the vegetable easily becomes a weed and may be found growing wild along the creeks and ditches in nearly all parts of the State. There is no reason why every garden should not have a sufficient supply for family use. Whether this vegetable may be grown for a canning proposition, we are not prepared to say. An experiment is now under way to demonstrate this point.

April 12, 1910, about one-tenth of an acre in the College garden was sown to three of the leading varieties of asparagus, i. e. Conovers Colossal, Palmetto, and Barr's Mammoth. Asparagus is slow in germinating. Five weeks elapsed before this seed germinated sufficiently to be seen. It has been thought that asparagus would not do well in this climate. This, however, has made a perfect stand and has grown as well as could be expected at any place. In fact, some of these plants have attained a heighth of more than two feet. At present, the one year roots are being dug for storage and planting next spring. The yield will not be less than 15,000 plants, or at the rate of 150,000 plants per acre. The culture of asparagus for the garden is very simple. It is only necessary to have the soil thoroughly prepared by deep plowing, and well fertilized by mixing with the soil not fewer than twenty to thirty loads of decomposed stable manure per acre. If the asparagus is to be planted in a small plot in the garden, the plants may be set in early spring in the ground in a trench, with the plants from one foot to eighteen inches apart. The plants should be set in a trench at least six inches deep, and covered with not more than two inches of soil at the time of setting. The roots should be spread out in the bottom of the trench with the crowns up. During the season, the trenches may be gradually filled so as to level the ground. When frost kills the tops in the fall they should be cut, and when sufficiently dry should be burned. This will help destroy the insects and fungus pests that trouble the plants. After the plot is cleared, it should be covered with a good coat of stable manure, which should be harrowed into the soil the following spring.

Beets.—All the different varieties of beets, including table beets, mangel wurzels, and sugar beets do well in Colorado. The table beets are easily grown. For early growing they should be planted as early in the spring as the soil can be worked. In high altitudes these are good for table use even into the winter. For the lower altitudes second plantings should be made in June, as those planted early in the season tend to overgrow and become pithy. No particular pests trouble the beets to any extent. The beets in the College garden were ready for market during the months of June and July.

Brussels Sprouts.—One of the vegetables that is almost unknown in the State, but is particularly adapted to the climate of Colorado is the Brussels Sprout. This vegetable is to all intents and purposes a cabbage and may be grown in the same manner as the cabbage. This plant instead of forming a single terminal bud or head forms small heads in the axil of the leaves. For success with this vegetable, it is best to grow it from seeds in hot beds or cold frames, and transplant to the open ground as soon as the weather will permit. The culture is the same as for the cabbage, and insect pests that work on cabbage also work on this plant the same as on cabbage, except that the Green Aphis is more prone to attack the sprout than cabbage. For treatment see cabbage.

Beans.—Theoretically, the bean family should be well adapted to the dry climate of Colorado. It has been found at least in Northern Colorado that the bean has more serious insect enemies than in most other parts of the country. Ordinarily the crop can be grown satisfactorily when the depredations of the striped flea beetle, and lady beetle can be controlled. Care must be taken in the culture of beans not to give more water than is necessary for the development of the plants.

Cabbage.—The cabbage is well adapted to Colorado conditions, particularly the higher altitudes. Growing this crop is becoming one of the commercial industries of the Greeley, Fort Collins, and Denver districts. Owing to the bulkiness of the crop, it has not been grown to any great extent in the mountain valleys of the State, although it is as well or better adapted to those conditions as on the warmer lands of the plains. Early cabbage should be started in cold frames or hot beds, and may be transplanted to the field or garden as soon as the soil can be worked in the spring, provided the plants have been sufficiently hardened off by exposure to the cold. In the College gardens, the Winningstadt variety of cabbage was set May 9th. These cabbage were ready for market the middle of July. Practically every plant made a firm head that weighed from two to four pounds. Cabbage for late use should be set in the field from the latter part of May until the first of July,

depending on the length of season of the place. At Fort Collins Cross cabbage set from the 25th of May until the 5th of July make a crop that is usually matured at the end of the growing season. For market cabbage, it is best to set plants sufficiently close to keep the size of the heads down to five pounds. At Greeley, where 50,000 pounds per acre have been grown, these cabbages are set in rows from 24 to 28 inches apart, and about 14 inches apart in the row; thus using 12,000 to 14,000 plants per acre. Cabbage require a maximum of fertility, particularly of nitrogen.

Two serious cabbage insects are found in Colorado. The most serious one is the so-called cabbage worm, the larva of a white butterfly. In reality there are two species of these worms. Their habits are so nearly alike, however, that they may be treated as one. The best remedy for these worms is to dust on the plants a light application of Paris Green or some of the other arsenical mixtures diluted with flour or lime. If this work is done before the plants are too large, there will be no danger from poisoning either human beings or stock. The green aphis is also frequently destructive to the cabbages. These are best controlled by spraying the plants when the aphis first attacks them, with some contact poison as tobacco decoction or kerosene emulsion. Ordinarily these aphids do not cause sufficient injury to warrant any treatment.

Cauliflower.—Cauliflower is one of the crops that is especially adapted to Colorado conditions, and should be in every garden, even if not for commercial purposes. Cauliflower matures even at an altitude of 8,500 feet. For the past three years this crop has been experimented with in a small way at the Agricultural College and in various parts of the State. This vegetable is peculiar in its demands of soil, climate, etc. In the East, where it is grown for market purposes, it is thought to be doing well if one-half the plants make heads that weigh from one to two pounds. In the high altitudes of Colorado, as in the San Luis Valley, Middle Park, and Aspen, it is not uncommon to find heads that measure 12 to 14 inches in diameter and weigh six to eight pounds. We believe this vegetable in a short time will be grown, not only for home use, but for shipping East to the big markets of the United States. The only difficulty in growing cauliflower in mountain districts is that where gardens or fields are near uncultivated areas, the prairie dogs, ground squirrels, and other small animals are apt to find the vegetables toothsome and are not willing to wait until the crop is ready for harvest.

During the season of 1910, plants were grown at the Experiment Station for experiments in different parts of the State. About 1,000 of these plants were sent to Del Norte. About the same to Grand county, and an equal number was set in the fields

of Fort Collins. Owing to accidents, neither of the lots sent out proved as satisfactory as was hoped. Better than 90% of those that were planted at Fort Collins made marketable heads. Two varieties, Early Snow Ball, and Extra Early Dwarf Erfurt, were used. The late planting was set June 15th and 16th. Up to the present, from one-tenth of an acre of cauliflower 785 pounds have been sold, bringing $42.30. A part of the crop is being held in storage to determine the advisability of keeping cauliflower after the season closes. Cauliflower demands cool weather and a soil that is fairly strong in nitrogen and also well supplied with phosphorus and potassium. The culture for this vegetable is the same as for cabbage, with the additional work of going through the field every day or two after the heads begin to form and tieing the leaves together to prevent the small white heads from coloring. If this is neglected until the head is colored by the sun, the vegetable is injured both for market and family purposes.

Corn.—Corn is a crop that is not well adapted to Colorado, except in the lower altitudes. Corn, requires warm days and nights to make its best development. While it is not advised to grow corn for market purposes, it may be grown in the home garden satisfactorily, except in the higher altitudes. The culture is the same as in other districts. It is well to give corn as little water as possible, as over watering serves to retard the maturity of the corn. The worst enemy of the corn is the so-called boll weevil, or corn worm, which feeds on the immature grain in the husks. No remedy is known for this insect. A succession may be maintained from the latter part of July until frost, by planting such varieties as Corey, or Catawba, for early, Crosby's 12 Row, second crop, and Country Gentleman, for late. At Fort Collins, these three varieties did very well during the past season. Stowell's Evergreen and like varieties are too late to be satisfactory with our length of season.

Celery.—Celery is one of the crops that is not only being grown for home use, but is being extensively grown in Colorado for market. Until within a comparatively short time, it was thought that celery could not be grown in the so-called arid West. It has been found, however, that celery not only can be grown in the West, but that the texture and flavor of Colorado celery is much superior to that grown in either Michigan or California. The celery crop this year in the so-called Denver district will probably amount to 400 cars. This does not include that grown in the Pueblo district, or for numerous markets in other parts of the State. There is no reason why celery should not be grown in every garden. Considerable complaint has been made by celery growers that the tendency of the plant to make seed stalks the first year is a serious

menace to the industry in the State. As a working hypothesis we have assumed that this trouble is due to some of the changes which the plant has undergone in being brought from a humid to a dry climate. In order to investigate this, a small area of both early and late celery was set in the College gardens at Fort Collins. The plants for this experiment were sown in flats in the green house, then pricked from the flats as soon as large enough into benches, 1½ to 2 inches apart each way. This gave sound, stocky plants for setting in the field. Great care was taken from the time the seed was sown that these plants did not suffer for water. Plants were set in the field May 27th and 28th. This date is rather early for Giant Pascall, which is intended for late crop, but was set early in order to induce the plants to go to seed if there was any tendency in that direction. The Golden Self Blanching, was set on either side of a ditch, making two rows about 12 inches apart. Plants were set 8 inches apart in rows. The Giant Pascall was set in single rows six feet apart, eight inches apart in the row. These plots were given clean cultivation at intervals of about one week, with a twelve tooth Planet Junior cultivator. The soil in these plots was kept thoroughly moist. In order to do this, irrigation was given at intervals of from three to five days during the whole summer. This kept the soil more moist than would be desirable for most plants. The Golden Self Blanching was bleached by tieing up the plants individually with old news papers. This method of bleaching proved satisfactory, except where the papers were tied so tightly that the new shoots in the center of the plant were prevented from making their way to the top. In these cases the new shoots doubled up and in crowding started decay. No plants of this variety showed any signs of sending up seed stalks. Nearly all of this was marketed during August. The Giant Pascall was left to grow until rather late in the season. In September furrows were turned to the rows and left for two or three weeks, then early in October the larger part of the plot was taken up and set in a trench for bleaching. This trench was prepared by throwing out a double furrow with a plow and then shoveling out the loose soil so the trench was made about 18 inches deep, and two feet wide. In this the celery was trenched, three plants wide and as close together lengthwise in the trench as the roots of the plant would permit. After setting in the trench water was allowed to run through the trench to firm the soil around the roots. The trench was then covered with corn stalks, and later with straw, old tomato vines and earth. A part of the plot was left where grown. These plants were banked sufficiently high to bleach, then as cold weather approached were covered with tomato vines, straw, etc. A few plants were also taken from the soil and placed in half barrels in the

cellar. This system may be utilized where only a few plants are used, and cool cellar room is available. Although the Giant Pascall made large plants because of having a longer season for growth than is usually desirable for the crop, there were but four or five plants in the whole plot that showed any tendency to go to seed. This would indicate that the cause of celery going to seed prematurely in Colorado is because of drying out of the soil sometime during the growing season. Celery in its natural condition grows in swamps, in other words it is a semi-aquatic plant. It is also a biennial, that is, it should make growth in one season, and develop seed the next the same as the carrot, parsnip, etc. The theory is that, in Colorado, the growth of the plants becomes checked by lack of water sometime during the summer season. This corresponds to the resting season over winter in its natural habitat. When growth starts again after the check the plant sends up its seed stalk. This experiment has not been carried far enough to demonstrate this theory beyond a doubt, but we believe that at least a large part of the trouble experienced by Colorado growers comes from this cause.

Celery growers in Colorado are troubled very little with fungus diseases or insect pests. Occasionally we hear of trouble from decay of the stem. This is undoubtedly caused by fungi. This has not been serious enough up to the present time, however, to lead to any particular investigation of the subject. Celery rust occasionally occurs, but this is not ordinarily serious. Few insects give any trouble.

Cucumber.—The cucumber is a semi-tropical vegetable, and is not supposed to be very well adapted to Colorado conditions. For all places, except the very high altitude, however, this vegetable may be grown with perfect success. While the cool nights are not particularly favorable to the growth of the cucumber, the absence of diseases that cause trouble in other places offset this difficulty to such an extent that the yields are on the whole practically as good as in the so-called cucumber districts of the East. The cucumber needs considerable moisture, and yet care should be taken not to cause a cooling of the soil from too frequent or heavy irrigation. In order to avoid this while the plants are small, the harrow should follow as quickly as possible after irrigation. Where the season is short, the seed should be planted early. The early varieties are to be recommended rather than the larger growing late varieties. The greatest danger to the crop is from poor germination of the seed, owing to the cool nights in the spring. It is well to plant plenty of seed and depend on thinning the plants down to the required number. In the Experiment Station plots, both Coy's Cumberland, and the Fort Hook Famous cucumbers made

good growth until the heavy frost of August 24th, killed the vines.

Egg Plant.—The Egg Plant is one of the least known garden vegetables and one that deserves being better known. This plant is related to the tomato, and requires the same conditions to make its best growth. As it is a warm climate vegetable, it is best to start the plants in the green house or hotbed and have them in blossom when the weather will permit setting in the field. This, at the altitude of Fort Collins, is usually about May 25th to June 10th. These plants should be given as little water as possible and frequent shallow culture. In the Experiment Station plots, Black Beauty proved to be the most valuable variety. Plants may be set two feet apart with rows three feet apart. The little black flea beetle and striped potato beetle are the most serious insect pests of this vegetable. The best remedy found in our plots was to spray the plants with a rather strong application of arsenate of lead. This should be done as fast as the plants are set out, as the flea beetle is apt to be at its worst about the time the plants are ready to be set in the field.

Melon.—Melon growing in Colorado, is so well known that little need be said in regard to it. The melon requires a warm climate and thrives best on a sandy loam soil. The Arkansas Valley district has been noted for several years for its high quality melons. Other sections of the State, notably the Lower Grand Valley and the Uncompahgre Valley, are rivaling the Rocky Ford district. The Greeley district is also producing melons in a commercial way. The soil of Fort Collins is not well adapted to melon culture, and none have been tried in the Experiment Station gardens.

Onion.—The onion is another vegetable that is becoming of commercial importance in various districts of the State. The requirements for the onion are rich loamy soil that can be easily irrigated and worked, and where sufficient stable manure can be obtained to keep the land in the very best condition. For this reason the onion industry is largely confined to areas close to the cities of the State. The greatest drawback to onion growing is the uncertainty of the market. The yields in the State are fairly uniform, and failures are rare. Yields of 300 to 400 sacks, that is, 600 to 800 bushels are not uncommon, but the average is much less than this. The onion requires a fairly long season to mature, therefore is best planted as early in the season as possible. In fact onion seed may be planted in the fall. In the Uncompahgre Valley where the spring is early the seed is frequently sown in February. The ground should be prepared by being preceeded by potatoes or some other hoed crop that will free the land from coarse vegetable fiber and weeds. It should be thoroughly harrowed and leveled

after being plowed, so as to make a fine smooth seed bed. Two systems of growing are used in the State. One, the flat system has rows 12 to 14 inches apart. The other is known as the double row system. That is two rows are close together, with a wider space between. In the Greeley district, irrigation is given by means of flooding. Few diseases trouble the onion crop. Occasionally some loss is sustained from onion rot. A small insect known as "thrips" cause considerable injury to the onion in this State. This insect is so small as not to be ordinarily noticed. A grayish appearance of the leaves and stems; together with a tendency of the leaves to twist, indicate the presence of this insect. This pest is not easily destroyed. About the only means of control is by spraying with some contact insecticide as black leaf sheep dip or a soluble oil. These are seldom very satisfactory, owing to the fact that the insects are for the most part between the leaves, where they are protected from the spray. The varieties mostly grown in the State are the Red Globe, Red Wethersfield, Yellow Globe Danvers, White Globe, and Prize Taker. Onions for family use may be grown in all altitudes and soils of the State. In heavy soils there may be trouble from the seed not being able to prick through the crust. This may be overcome by keeping the soil moist at the time plants are appearing through the ground. In keeping onions for winter, it is best to have them in a cool dry place.

Peas.—Peas are well adapted to practically all districts of Colorado. Northern Colorado is becoming noted for its production of the garden pea for canning purposes. Factories have been established at Longmont, Loveland, and Greeley. The cultivation of this plant is very simple. For garden use it only need be planted early in spring, in drills from two to four inches deep. The wrinkled varieties are somewhat prone to rot in the ground when planted in heavy soil. Few insects or plant diseases trouble peas in Colorado.

Pepper.—The pepper is similar to the egg plant and tomato, so far as soil requirements are concerned. The plant does its best in a rich warm soil. It may be grown, however, in any of the agricultural districts of the State, provided the plants are started early enough to have good sized plants to set when the soil is sufficiently warmed for planting in the field. The seed of the pepper is very slow to germinate, so that plants should be started earlier than for tomato, or cabbage.

Salsify.—This vegetable is comparatively little known, but is desirable as a winter and spring vegetable and is recommended for the home garden. The culture of this plant is very simple. Seed may be sown in drills in the garden at any distance apart that may be desired. The seeds are almost sure to grow, so that a good stand

may be expected. In the fall the roots may be dug and stored in the cellar, or left in the ground until wanted for use. When stored in the cellar they should be covered with soil or sand to prevent shriveling. It is thought by some that freezing improves the quality of the root. Rust frequently attacks the leaves of this plant, but is not usually serious enough to make an appreciable difference in the size of the roots.

Squash.—The squash is somewhat uncertain from a standpoint of production. Some years this vegetable produces so heavily as to be exceedingly profitable, even though the price is not high. Other years the yield is scant. This seems to be more a matter of the season, than from any organic difficulty. The culture of the squash is simple. A warm dry soil is most favorable to its development. Some particularly good specimens of Warted Hubbard, have been grown in Northern Colorado districts. The smaller varieties as Burpee's Ford Hook, are better adapted to the higher altitude and short seasons. One of the worst enemies of the squash is the so-called squash bug. This insect is hard to destroy as it cannot be poisoned. The best remedy, where only a few plants are grown, as in the garden, is to lay pieces of boards on the ground near the plants. The insects will collect under these boards during the night, and may be killed early in the morning.

Tomato.—Tomato growing in Colorado is becoming one of the agricultural industries. This crop has been grown in the Arkansas Valley for quite a number of years, but in the past few years, tomatoes have been grown in the Northern Colorado district from Denver to Greeley for canning purposes. Until recently, nearly all the canned tomatoes of commerce were put up in the eastern states, as Michigan, Delaware, and New Jersey. There the seasons are somewhat more favorable for securing larger yields than in Colorado. However, the yield here is oftentimes equally as good as in the eastern states, and the quality is superior. The tomato thrives in a warm, sandy soil. For that reason this plant demands frequent shallow cultivation. Tomato growing in a commercial way is confined to the lower altitudes in the State. For home use this vegetable may be grown at an altitude of 7,000 to 8,000 feet. In the high altitudes, particular care should be taken to have the plants as large as possible when the ground is ready for setting in the open field. In the Experiment Station gardens, tomatoes were set this year on several different dates. The first setting, made May 10th, was injured by the freeze of May 16th to such an extent that it was necessary to reset plants although the plants first set were well hardened. The second setting was made May 25th. June 4th, two rows of Earlina plants were set that had been grown in six inch pots in the green house. These toma-

toes were in blossom at time of setting, and were not disturbed sufficiently to check the growth. The first tomatoes picked, July 23rd, were from this plot. June 15th another plot of Earlina tomatoes was set. These plants being set so late, never reached a sufficient size at maturity to make the yield that the earlier set plants made. The area of the whole plot was 28/100 of an acre. From this two and one-half tons of tomatoes were picked. The soil of these plots is not well adapted to tomatoes, nor is the climate of Fort Collins considered to be as well adapted as places farther out on the plains. As a result, few tomatoes are planted in this district, and prices are always higher than in Greeley or the other canning centers. For this reason it is an incentive for the enterprizing gardener to grow this vegetable where it is not ordinarily grown. For the high altitude, it is best to select the earliest maturing varieties as Burpee's Early, Spark's Earliana, June Pink, etc. The seed should be started in the green house or hot bed about April 1st. As soon as the plants are sufficiently large to prick out, they should be put, either in other flats one or one and one-half inches apart, or they may be transplanted directly to the hot bed or cold frame as the case may be. They should be, at least, one inch apart, and two inches apart each way is better. These plants should be from six to ten inches high when set in the open ground. If space is available so that plants may be grown individually in four to six inch pots, two or three weeks may be gained in securing early fruits. In any case, great care must be exercised to see that the plants are thoroughly hardened by exposure to the outside air, before being set in the field. Otherwise, a cold wind even several degrees above freezing, when first set, will frequently kill the plants. On the Eastern slope, the potato flea beetle, and the striped potato beetle are serious pests to the tomato. Our experience in this line so far has led us to favor spraying the tomato plants with a strong mixture of arsenate of lead and water, as fast as the plants are set in the ground. This either prevents the insects from working, or kills them if they attack the plants. None of the leaf fungi that are so destructive to the tomato in the East are troublesome in Colorado, nor is there any serious trouble from rotting of the fruit. One soil fungus, Fuserium, occasionally causes losses in the fields. As yet, we are not certain whether this fungus is native in the soils, or is carried to the fields with the plants from the cold frames. The first indication of the trouble is a yellowing and withering of the leaves, followed by shriveling of the plant. If the plant be examined, it will be found that the stem under the ground and above ground also is discolored throughout the vascular system, or sap wood. There is no known remedy for this disease. It may be partly prevented by making sure that the seeds are sown and

plants grown in soil which has not grown tomatoes before, and in rotating the crops, so that tomatoes do not follow tomatoes.

A CABBAGE BREEDING EXPERIMENT.

The Cross cabbage, which is extensively grown in Greeley for shipping, is believed to be an accidental cross between the Winningstadt, and Henderson's Flat Dutch. This cabbage is globe shape in form, and is about half way in season between its two parents. Since the origin of this variety at Greeley by Mr. John Levy, the seed has been grown at that place, so that the variety has been kept practically as first introduced. This cabbage has proved very desirable in the district, but has had one serious failing. Great care has been exercised by those who grow the seed to select heads that were true to type for growing the seed. Notwithstanding this precaution, there is quite a per cent. of the crop that has reverted each year to one or the other of the parents, that is, there are always in the field, many heads that are flattened as the Flat Dutch, and many that are pointed as the Winningstadt. Some of the growers have laid this to uncongenial soil or climatic conditions under which the cabbages were grown. According to Mendel's law, some of these plants should have an inherited tendency to revert each year to the original parentage. In order to ascertain if this principal were true with cabbages, and also to eliminate the trouble if possible, an experiment was started a year ago. First, individual heads of this type were selected in the fall of 1908 for growing seed the following year. In the spring of 1909, several of these heads were planted separately in different places where there would be no chances for the seed to cross pollinate. The rest of the heads were planted in a single row in a garden. All the plants that were set by themselves were sterile or practically so; only a few small seed being developed. Seed was saved from all of the other plants separately, as well as from the several plants from a field at Greeley. These seed were sown separately in the spring of 1910. Later they were transplanted to the field, and stakes set so as to mark off the progeny of each separate plant. Some interesting and valuable results have followed. Of the fifty plants whose progeny was set in the field, only four plots produced heads that were all true to the Cross type. Great variations occurred in the rest of the plots. Some were pointed, following the Winningstadt type, both in shape and earliness; others followed the Flat Dutch, the other parent. In many plots flat, pointed and globe cabbages all came from the same plant. The plants from the plots that were all true to the type have been saved for further experiment, as have also some of the heads of good type from the plots that had various types. Theoretically these plants that are all true to type this year, should continue true to this type. If this proves true, the trouble from changing the type of head will be at an end.

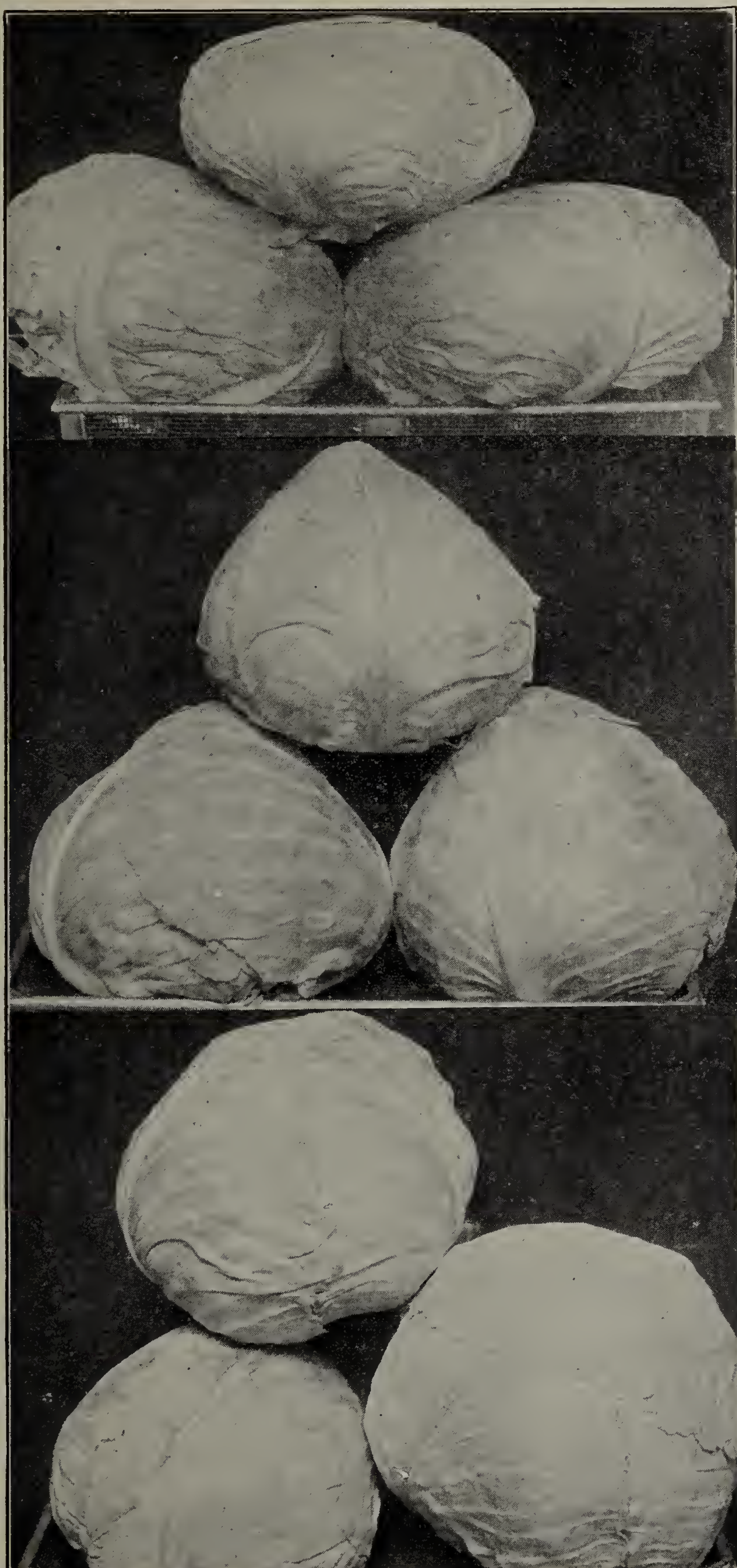

PLATE II.—CROSS CABBAGE.—Upper and middle figures, reverted to Flat Dutch and Winningstadt; lower figure, true type of Cross.

HINTS FOR GARDENING.

Colorado ranchmen have the reputation of not liking the so-called intensive employment. A trace of the old horse-back farming is still to be found in the ideas of most Colorado farmers. For this reason few farmers take kindly to the hoe. Methods in gardening have improved the same as methods in all other branches of agriculture. It used to be thought that onions, strawberries, etc., should be grown in a so-called bed; a little space of ground ten feet wide by twenty feet long. It is found to be much more economical of time and labor if all garden vegetables are treated in more or less the same way as our field crops. The ground should be prepared as for a crop of potatoes or grain. If a garden is to be made with several of the perenniels as rhubarb, horse radish, asparagus, etc., it should be planned so these may grow all together on one side of the garden. This strip may be left without plowing and will not interfere with the breaking of the rest of the plot. It is well to start the garden next to these plants and run the rows in the same direction. Not less than three feet of space should be left between rows of all garden crops, including onion, lettuce, etc. Where it is desirable to economize space, many of these smaller vegetables may be put in what is known as the double row system. That is, two rows are planted from six to twelve inches apart, then a space of three feet is left for cultivating. There is always a tendency to crowd all vegetables, with the result that the size and quality is frequently sacrificed. The first row should be marked with a line. If a garden drill is to be used the marker will mark the rows ahead so that the line need not be used further. Where a garden drill is not used, it may be desirable to stretch a line and then make a mark by running a bicycle over the ground under the line. If a single wheel is used for this purpose the row will be more or less crooked. Where the bicycle is used, the second wheel corrects the inequalities of the front wheel so the mark will be pretty straight.

Where irrigation is practiced there is always a tendency to use a great deal of water, and to do little cultivating. It is always better to use little water and more cultivation. Thorough frequent cultivation prevents evaporation, and makes plant food available as well as keeping the weeds from getting started. The garden should be cultivated not less than once a week until the plants are too large to get through with a horse. For corn and vine crops as squash, cucumber, etc., it is well to make the space between the rows greater than three feet. An abundant supply of well decomposed stable manure will help to warm the soil and mature the vegetables where the altitude is high and the seasons short.

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p. 4

Bulletin 173 November, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

NOTES ON A DRY LAND ORCHARD

By J. E. PAYNE

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1910

PLATE I.—1. Tree No. 1 just before it was dug. Right side of top dead and left side poorly developed.
2. Roots of Tree No. 1. Long roots on right show development on side of tree which was alive.
3. Stump and some roots of tree No. 2.

NOTES ON A DRY LAND ORCHARD

By J. E. PAYNE

In 1894, a few trees were planted at The Plains Substation at Cheyenne Wells. These consisted of a few each of cherry, plum and apple trees. Some gooseberry plants were set out at the same time. Among the apple trees planted were four Wealthy trees which were headed about five feet high. These were set at the regulation depth—two or three inches deeper than they had been in the nursery row. These Wealthy trees were planted in a row along the east side of the main apple orchard, between the apple orchard and the house yard. It happened that the space west of the trees was kept cultivated up to the time of digging the trees out, while the space east of them had not been cultivated since 1903. By 1910, two of the trees were dead and the two remaining were in bad condition, especially on the east side of each tree.

In 1905, the main orchard was planted in deep-plowed ground. The trees set this year were set in holes dug in dead furrows and about half a barrel of water was put into each hole before planting the trees. It was a very dry time when the trees were planted, but all of them lived. These trees were set only a few inches deeper than they grew in the nursery. All were headed rather low. These trees all grew well. The orchard was kept cultivated so that few weeds grew there. Several trees were killed by rabbits the first winter after they were planted, but only one died from other causes, and it seemed to have been diseased when first set out.

In 1897, the vacancies in the orchard were filled with apple trees which were shipped from an irrigated nursery. All these trees were headed from four to five feet high. As the high-headed trees set in 1894 had grown very little during the three years they had been planted, it was thought best to set these deep enough so that the heads would be the proper height. Deep holes were dug, and they were planted two to two and a half feet deeper than they grew in the nursery. They all grew well and were soon larger than the trees planted in 1894. In the spring of 1910, these deep-set trees were as large as some of the trees set shallow in 1895.

When the orchard was planted, the trees were set so that each tree occupied a space nearly twenty-three and one-half feet square. When the orchard was inspected in the spring of 1910, branches were almost meeting in many places. When the orchard was trimmed, one-third of the trees were marked for cutting out in order to give room for further development. At this time, the trees were from six to twelve inches in diameter at the ground.

This orchard had grown entirely with the water which fell

upon its surface, except such as was brought to it during the first twelve years by a few furrows which carried storm water from about forty acres of prairie. But it had received no water from this source since 1907, when the prairie adjoining was plowed. During three years, it produced quite good crops of apples, and some fruit has been borne every year since 1900.

The Substation orchard is one of the best Dry-Land orchards in eastern Colorado. But, its history shows that the trees have needed extra water at some time during the year every year since they began bearing fruit. If, at this critical time, a barrel of water could have been given to each tree, much more fruit would have been borne and it would have been of better quality.

The foregoing paragraph applies especially to apple trees. The cherry and plum trees produced good crops without extra water nearly every season until they began to suffer from old age. But, it is quite probable that they too would have given larger returns had they received extra water at some time during the year. By 1910, all the plum trees and nearly all the cherry trees were dead. Gooseberries bore well during the years 1896-1900. By that time, they needed thinning and resetting. As this was not done they bore but little fruit during the later years.

Forest trees were planted for windbreaks around the orchard and along the north side of the farm. Honey locust, black locust, Russian mulberry, White elm and Box elder have all done quite well. Russian mulberry bore considerable fruit while left untrimmed. After they were trimmed, they bore sparingly. Some trees bore fruit with fine flavor, while the fruit borne by other trees was insipid, and quite worthless.

ROOT SYSTEMS OF APPLE TREES.

As we were destroying trees, we thought it well to get some facts concerning the development of the root systems. In August, 1910, we dug up four apple trees and examined the root systems, tracing the roots to their ends or until it was impracticable to trace them farther. One tree was a Wealthy which was set shallow in 1894, one was a Wealthy which was set deep in 1897, one was a Mann which was set deep in 1897, and the other was a Ben Davis which was set shallow in 1895.

Tree Number One.—This was one of the Wealthy trees which were set shallow in 1894. It was headed high. It was kept cultivated on all sides until 1903. From 1903 until 1910 the ground on the west side was kept cultivated, while the ground on the east side was not stirred. When dug up, the top of the tree was dead on the east side. Only a few short roots were found on the east side. These grew about five feet horizontally and only one foot deep. But, on the west side four strong roots were traced ten to twelve

feet horizontally where they were still nearly one-half inch in diameter. Judging by other roots which were traced out more completely, these roots were probably fifteen or twenty feet long. None of them grew deeper than fifteen inches. The tree was three inches in diameter. The west side of the tree was alive, but was in bad condition. Plate I, Figure 1 shows the tree as it stood in the ground, and Figure 2 shows a view of the roots.

Tree Number Two.—This was a Wealthy tree which was planted deep in 1897. Its trunk was seven inches in diameter. It was found that the roots grew upward until they came near the surface, and then grew outward or downward according to the soil. Twelve roots of this tree were traced from five to ten feet horizontally from the tree where they were cut off when still one-fourth to one-half inches in diameter. Six of them turned down when three to ten feet from the trunk. These all followed holes which had been made by burrowing animals. Two were traced three feet, one four feet, one five feet, and two five and one-half feet deep. And they were from one-fourth to one-third inches in diameter when cut off. But nearly all the real feeding roots of this tree were in the upper eighteen inches of soil. In few cases during the work of digging out all the trees were roots found going more than three feet deep, excepting those which followed holes. The upper eighteen inches of soil were filled with fibrous roots. Roots from other trees were found interlacing with the outer ends of the roots of all the trees. One view of the roots of this tree is shown in Figures 3 and 4 which shows the tangle of roots starting from the trunk. The subsoil here contained many large lumps in which they were found many white flakes which are supposed to be compounds of lime and magnesia. The roots seemed to have tried to avoid these lumps, going around, over or under them rather than through them. We expected to find many roots above the graft on these deep-planted trees, but none were found on either this tree or the other deep-set tree which was dug out.

Tree Number Three.—Tree number three was a Mann apple tree which was set two and one-fourth feet deep in 1897. It had grown well and its trunk was about seven inches in diameter at the ground. Plate II, Figure 4 shows this tree with roots dug out. The top of this tree spread about eight feet in all directions. The extreme tips of the roots, traced until they were only one-fourth inches in diameter, spread 33 feet. A few of these roots were traced three feet deep. The roots of this tree occupied the upper eighteen inches of soil quite fully in a space 30 feet in diameter. Many of its roots were traced 15 feet from the trunk. The tree had a well-balanced top, and its root system showed a good distribution through the soil on all sides.

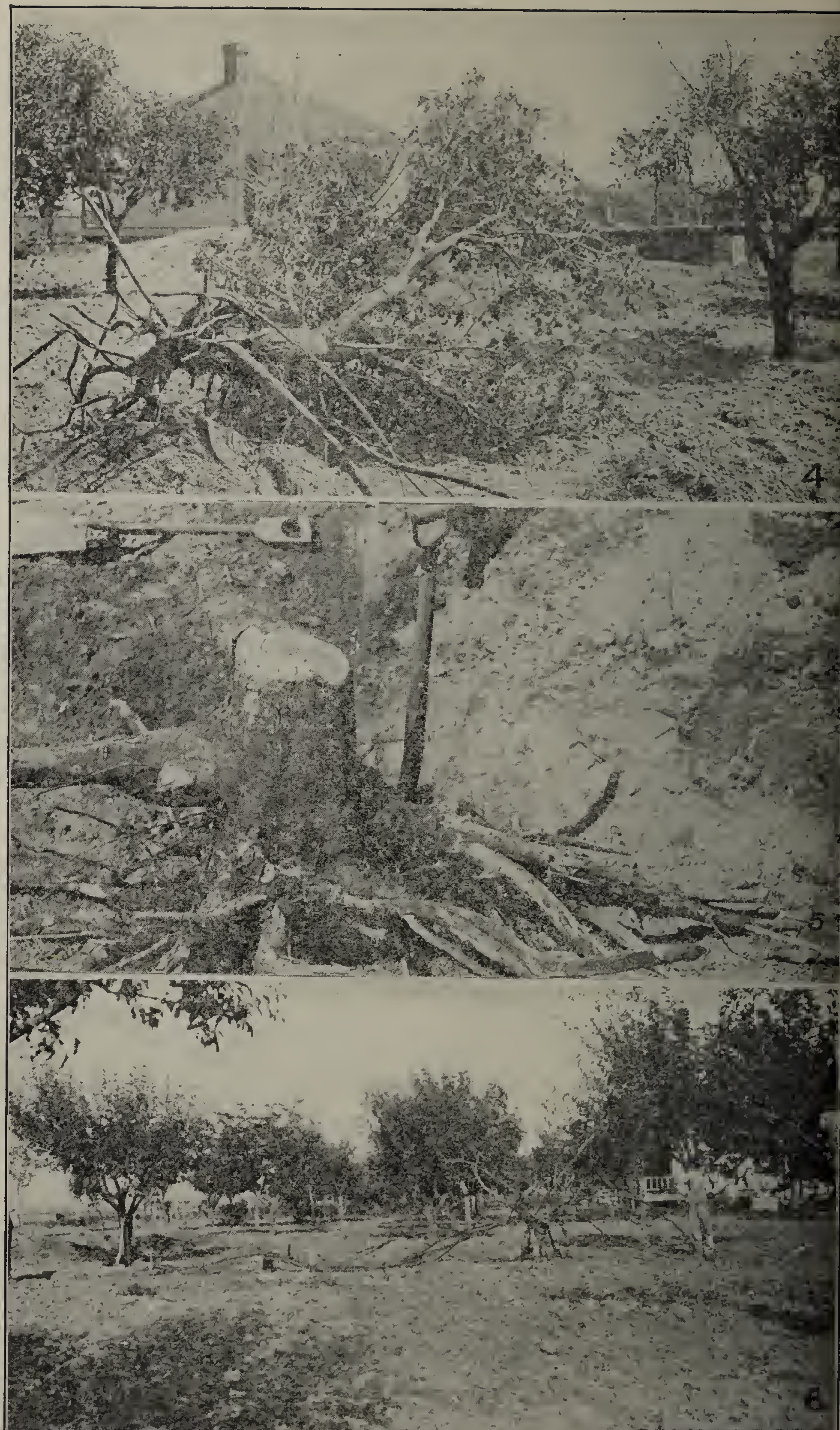

PLATE II—4. Tree No. 3 with part of its roots. The roots spread 33 feet.
5. Stump and large roots of tree No. 4.
6. Roots of tree No. 4 showing roots spread 33 feet.

While digging out this tree, roots of black locust were encountered 30 feet from the nearest black locust tree. In other parts of the orchard, we found roots of black locust 60 feet from the nearest black locust tree.

Tree Number Four.—This was a Ben Daivs apple tree which was planted shallow in 1895. It had a well-balanced top, and was eight inches in diameter at the surface of the ground. It had grown well and had borne several crops of fruit. It was healthy when cut down. Some of the roots of this tree were quite large, measuring as much as three inches in diameter where they joined the trunk. This tree stood where it got water from the prairie whenever a heavy dashing rain fell. This made conditions favorable for rooting deeply. One root was traced five feet down, one was traced four feet down and several were traced three feet down. But, the most of the feeding roots remained in the upper eighteen inches of soil. The main roots were found growing most of the distance within one foot of the surface. Fifteen of the large roots were traced distances varying from eight to twenty-six feet. One root was one-half inch thick at 17 feet and was still one-eighth inch thick when broken and lost at 26 feet from the tree. Another was traced 21 feet. The remaining 13 were traced from 8 to 15 feet. These were all cut when one-third to one-half inch thick. The stump with roots attached is shown in Plate II, Figure 2.

In digging out this tree, a Russian mulberry root was found which was traced 50 feet from the nearest mulberry tree. This accounts for the stunted appearance of some apple trees which were planted close to Russian mulberry trees.

CONCLUSIONS.

1. Trees used for windbreaks for orchards under dry farming conditions are expensive unless the trees of the windbreak group are planted far enough from the fruit trees so that the roots of the windbreak group will not compete with the fruit trees for moisture. The root development of the Russian mulberry and black locust found at The Plains Substation indicate that the windbreak group should be planted 100 feet from the fruit trees.

2. Roots of apple trees do not feed deeply here. If the ground about the ones dug up had been plowed twelve inches deep nearly all the large roots would have been broken.

3. The roots of these trees grew deeper when the soil was wet below the normal depth.

4. Deep planting of trees did not decrease the rate of growth. Neither did it alter materially the position of the feeding roots.

5. The Dry-Land orchard is not considered as a commercial proposition, but it will pay every settler to plant a few well-selected trees and take extra care of them. Nearly all settlers plant more trees than they find time to care for, so they lose all.

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Adobe as a Building Material for the Plains

BY

J. W. ADAMS

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FORT COLLINS, COLORADO
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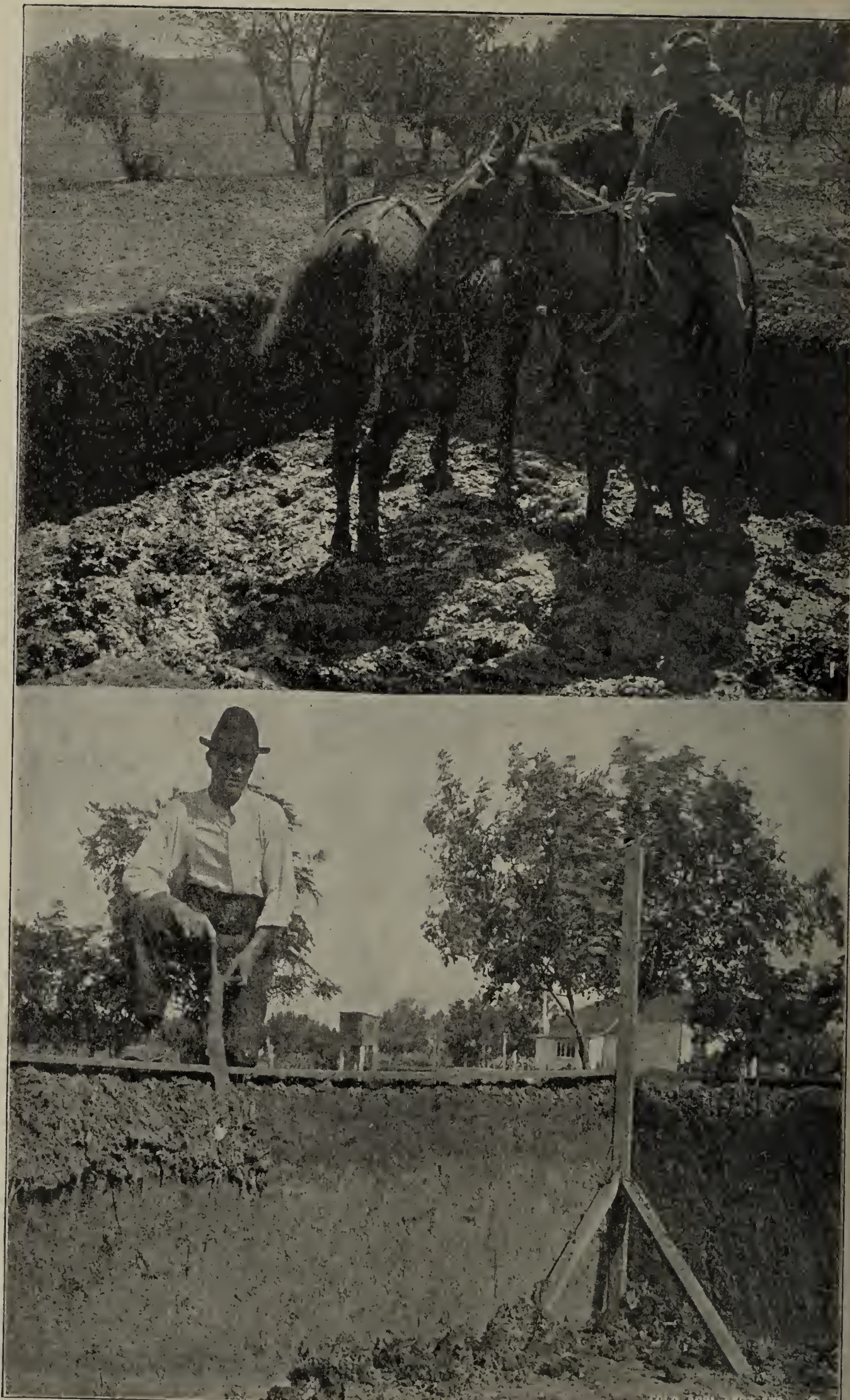

PLATE I.—1. Tramping the Abobe. 2. Trimming edge of wall with hay knife.

ADOBE AS A BUILDING MATERIAL FOR THE PLAINS.

By J. W. Adams, Superintendent of Plains Sub-Station

To the settlers of the plains, the subject of building material is of great importance. Comfort, cheapness, durability, and neatness of appearance are the elements considered in selecting building material for the homestead.

In this connection, we should like to call the attention of the settlers of the plains to the adobe buildings, or "Dobeys," as they are commonly called. These should not be confounded with the sod buildings. I do not wish to cast any reflections upon the "Soddy." It has served, and is still serving a good purpose as a cheap, comfortable house; but, at best, it is only a makeshift until the owner can build better. The "Soddy" is always settling and cracking the plaster, thus annoying the the housewife. The sod wall is an ideal harbor for mice and rats, and it is usually short-lived.

Not so with the adobe building. An adobe house, properly built, will cost no more than a sod house and yet be as permanent, attractive and comfortable as it is possible to build a house. They do not settle after they are dry. Mice do not work in them if they are protected at the foundation. They are superior to concrete or cement block houses in that they are non-conductors of heat and cold. They never sweat or become frosty on the inside, and rain does not wet the walls through as it does in many concrete houses. The labor required to build an adobe house is no more than that required to build a similar house of sod or concrete.

At the Plains Sub-station, at Cheyenne Wells, we built during the summer of 1910 three adobe buildings which have attracted so much attention and favorable comment that we have decided to publish this bulletin describing these buildings, giving cost of material, time required to build them, and describing the process of building so that any person desiring to build such buildings may do so.

We erected these buildings on concrete foundations eight inches high. This is not necessary, if one is always careful to keep the buildings banked up to prevent water settling around them. The concrete foundation is desirable, however, as a protection against mice and rats. These foundations were very cheap, as we used old cement blocks from a burned building to mix with the concrete. If rock of any kind is available the foundations need not cost much.

In planning a building of this kind, we should consider the kind of roof to be used and make the dimensions such that it may be covered with the least possible waste of material. The dimensions being decided upon, stake out the foundation carefully. If concrete foundation

is to be used it will be necessary to make forms for the foundation. Then set good straight posts in each corner and at intervals of 14 or 16 feet on the inside of the wall. Line and plumb these posts very carefully. If desirable, short stakes may be used instead of posts until the walls get above the stakes, then these may be replaced by posts as high as the walls are to be. Good, straight 2x4 posts are all right. The stakes being lined and plumbed carefully, you are ready to begin the wall.

Now, take your sod plow, select a patch of prairie where the grass is thick and tall—if possible, (avoid sandy soil) and plow a thin sod. You may plow enough at one time for the entire building, if desired. Select a place for mixing the adobe near your water supply, if possible. With small buildings, it may be desirable to mix the adobe in the center of the building, but it will not pay unless your building is so located that you cannot drive around it. Haul your sod and spread it in a circle not to exceed twelve to fourteen feet in diameter. Make the pile about eight inches deep. Now, throw water on this pile until you think you have enough to wet the whole pile thoroughly. Then, get on a horse and lead one or two others (see cut) and make the horses tramp around and around, turning very short. If they are allowed to go in a larger circle they will avoid stepping on the higher places. After you have tramped a few rounds, you will discover dry places in the pile. Throw more water on these places, and continue tramping and throwing on water until the whole mass is mucky. The pile will have a tendency to spread out and some places will be sloppy while others are not wet enough. Then, lead your horses out and take a manure fork (a six-tined fork is best) and throw the outer edges of the mass toward the center, taking care to throw the drier parts to the wet places and vice versa. Tramp again, adding water if needed. It is usually best to throw the edges in the second time in order to get the mass evenly mucked.

If you have been unable to get sod with plenty of grass and roots to form a fiber in the mud you should add a small amount of straw, hay or trash of some kind. Spread it over the mass after it is mixed as above described and tramp again until the straw is all tramped into the mud. When the mass is thoroughly wet and thoroughly mucked, and of such a consistency that it can be handled with a manure fork it is ready to be put into the wall. Throw this on a wagon or sled, discarding any chunks that have not been mucked, draw it alongside the wall and place it in the wall with a fork. Drop it into the wall with sufficient force to make it settle together solid, leaving no holes or spaces. Make as thick a layer as you can without its spreading out too wide. Let it spread over the edge of the wall an inch or two on each side. Be sure that the mud comes out to the edge of the wall at all

places, otherwise there will be holes, or flaws, in the wall when trimmed As soon as you have made one layer around the wall, if the weather is hot and dry, you may be able to start around again placing a layer on top of the first, being careful to make the mud fit down on the first clear out to the edge of the wall to prevent flaws. When you have a layer about 12 inches thick let it stand until it is firm but not dry. Select a board with straight edges fourteen to sixteen feet long and as wide as the thickness of the wall. If the wall is to be more than twelve inches thick, two boards of the proper width may be cleated together to make the required width. Lay the board on top of the wall with one edge against the posts, get upon the board and trim straight down each edge of the board with a hay knife (See illustration). When the walls are trimmed all around in this maner they are ready for another layer of mud. Continue until the walls are the desired height. Never allow a layer to become hard before it is trimmed or you will have a hard job.

The rapidity with which this work may be pushed depends upon the weather. If the weather is hot and dry, you may be able to make an average of six inches per day from start to finish. Some days you may put a foot and then let it rest a day or two. If the weather is cool or damp the work will go correspondingly slower. In early spring or late fall, the work is very slow, and one should not attempt to build adobe in winter.

Keep watch of your walls. If they are not drying rapidly, you had better lay off a day and allow the walls to dry. It is a very good plan to build two or theree feet and then let it stand a week or so and then build two or three feet more and so on until the wall is done.

The frames for doors and windows may be put in place and the mud built to them. But, a better way is to trim the openings for doors and windows, and fit frames into the openings as soon as the walls are as high as the frames are to be. These frames should be of two-inch stuff. The top of the frame should be as wide as the thickness of the wall and should extend into the wall a little. When the frames are in place you may build over them with the adobe. The walls will shrink in drying and draw away from the frames a little, leaving a crack. These cracks may be plastered up with a trowel.

If the roof is to be of shingles or iron, it will be necessary to anchor the plates to the wall to prevent the roof blowing off. This may be done by putting fourteen-inch bolts through short pieces of two-by-four and planting them in the walls as you build so the top of the bolt will just reach through the plate. If adobe or sod roof is to be used, the weight will be sufficient to prevent blowing off. The roof should be leak-proof to prevent water running down the walls and softening them.

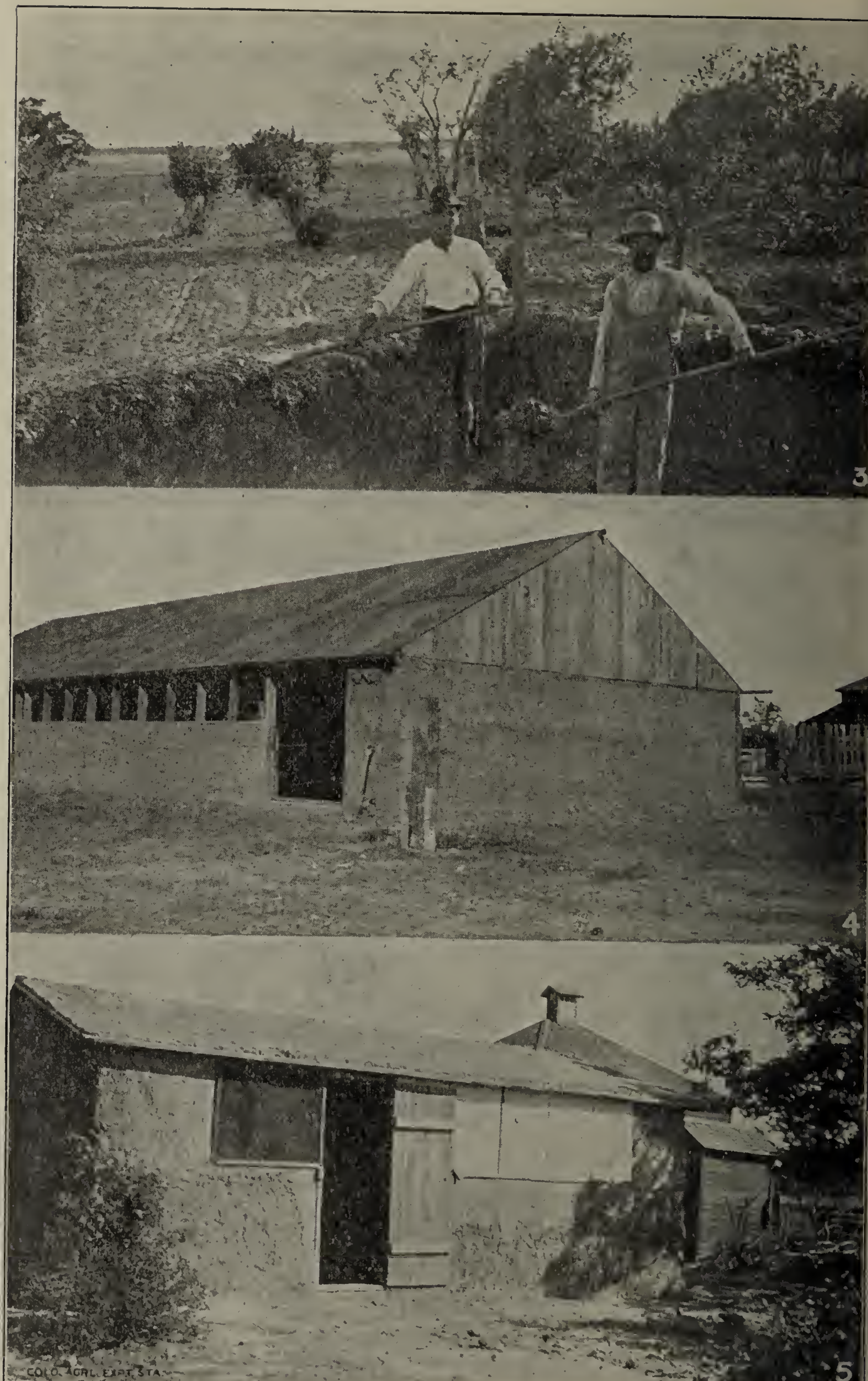

PLATE II.—3. Building the wall. 4. Cow barn 26x60 feet inside. 5. Poultry house.

We built at the Station this year a cow barn, a hen-house and a smoke house, or store room. The cow barn is 26 feet wide and 60 feet long, inside. The walls are twelve inches thick and seven feet high, with concrete foundation eight inches high. On the south side, the walls were built only four feet with adobe. The remaining three feet is framed with two-by-six lumber and enclosed with muslin curtains. (See illustration. The picture was taken before the curtains and doors were on.) These curtains furnish light and ventilation without draft. The roof is of corrugated iron. The rafters are 2x4x16 placed two feet apart, with cripples at the splice in the iron and one in the middle of the iron to prevent sagging. The iron is nailed to iron at edges, lapping two inches. The rafters are supported by two rows of 4x4 posts—four feet on each side of the center of the building. At the top of these posts, a 2x6 is spiked for the rafters to rest upon. The iron was painted on the under side and in the splices before it was laid. The upper side was painted after it was laid. The gable ends are boarded up with shiplap. Eighteen feet of the west end is partitioned off for feed, and a large door is left in the gable end through which to throw feed. On the south, there are two doors. One is three feet wide, hung on hinges, and the other six feet wide, hung on tubular track.

We have two rows of swinging steel stanchions supported by the same posts which support the roof, leaving a nice feed alley between the mangers. Twenty-eight feet of the barn has concrete floor with gutters and troughs of concrete.

The cost of the building in cash and labor is shown below:

Cement in foundation, \$6.60, floor \$23.40		\$ 30.00
Lumber for entire building		232.74
Total		\$ 262.74
Man labor	601 hours	
Team labor	142 hours	

Poultry House.

The poultry house is 14x20 feet, inside. The end walls are 12 inches thick and the side walls are 10 inches thick. The walls are six feet six inches high at the eves, and nine feet high at the gable. The south wall is only three feet six inches of adobe, the other three feet being framed and curtained in winter, and screened in summer.

The roof is made by laying joists, of 2x6 lengthwise about three feet apart. The ends are toenailed to blocks laid in the adobe. The middles are spliced and rest on posts. Shiplap is laid on the joists, and a kind of tar paper or rubberoid is laid on the shiplap. This is

covered with adobe such as is used in the wall. The adobe protects the paper and adds weight and warmth to the roof.

The house is plastered on the inside with a mortar made of sand and common soil. We used as much sand as could be put in without making the plaster crumble. It has not cracked at all and is as hard and smooth as lime plaster, but it will not stand wetting. This makes as good a poultry house as it is possible to make. It is neat, warm and light. The muslin front furnishes light and ventilation without draft.

The cost of building is shown below:

Cement $1.80, lumber, nails, etc. $29.44		$ 31.24
Man labor	114 hours	
Team labor	42 hours	

STORE ROOM, OR SMOKE HOUSE.

The smoke house is 14x14 inside. The side walls are 10 inches thick and the end walls 12 inches thick. The height is seven feet at the eaves and nine feet at the gabels. It is built on the same plan as the poultry house, except that we have two four-light single-sash windows instead of curtains. It is plastered with cement instead of earth. We have four 2x4 pieces crosswise just beneath the plates. Boards can be laid on these to form a small attic in which to store things.

The cost is as follows:

Cement $3.00, lumber, nails and paper $21.87		$ 24.87
Man labor	131 hours	
Team labor	42 hours	

The question will probably be asked why it took so much longer to lay up the walls of the smoke house than to lay the walls of the poultry house when there is really a little more wall in the latter. This can be easily explained. The men who laid the poultry house walls had continuous work and the advantage of experience and knew just how to go at it. But, the smoke house was built at odd times, and by severel different men, each having to learn his trade

THINGS TO BE EMPHASIZED.

1. Line your posts and plumb them carefully, and your walls are bound to be straight and plumb.
2. Be sure to make good joints between layers.
3. Never allow adobe to get hard before trimming.
4. Never allow dry or untramped chunks of sod to enter the wall.
5. Never allow water to settle against the walls.

Cement and block off on the outside and you have a very attractive and durable house.

Bulletin 175 November, 1910

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

The Potato Industry of Colorado

By C L. FITCH and E. R. BENNETT

POTATO INSECTS

By S. ARTHUR JOHNSON

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FORT COLLINS, COLORADO
1910

PLATE II.—THE COLORADO WILD POTATO (Solanum Jamesii)
1.—Habitat at Tiffany, near Durango. 2.—Size of Tuber as compared with Rurals
3.—A wild plant with two blossoms and seed ball

THE POTATO INDUSTRY OF COLORADO

By C. L. FITCH and E. R. BENNETT

PREFACE.

When the cattlemen first established their home ranches in our mountain valleys and in the creek bottoms on the plains, they found the dark, sandy, alluvial loams good potato soil, rich with the wash and willow leaves of ages, and large returns were secured for years on these soils. The introduction of alfalfa from Utah and California made the bench lands even more productive, and when farmers learned how to break and handle the alfalfa sod, it proved the greatest factor in the extension of potato growing and of irrigation development generally. The total output was doubled from the same areas in a few years' time and the possibilities of profit woke up the state.

A little later the fine shape and wonderful quality of mountain potatoes became known outside the mining and lumber camps, and railroads saw the possibilities of agricultural freight, and farm development.

Somewhat later the newer districts made so many demands upon the Agricultural College for advice and instruction that the Board of Agriculture secured a potato specialist to work for the growing industry. The attention of growers and of business men generally was called to the geographical position of Colorado with reference to the production and consumption of potatoes and the specialist went up and down through the mountains as an instructor and adviser to the newer potato districts. In connection with the Rio Grande Railroad and the department of Farmers' Institutes, Professor Cottrell took expert potato growers to the newer mountain districts, and later three special institute trains were run by the railroad and the college that were of great use, both to the railroad and to the people along its line.

In 1895 Colorado put in 37,000 acres of potatoes and produced three and one-half million bushels and ranked as the twentieth state in the Union in total potato production. Next year she was twenty-second. In 1900 she was twenty-third. In 1902 Colorado rose suddenly to sixteenth place in the Union. In 1903 she was tenth, and since that time she has held about that position. In 1906 her crop fell to the sixteenth, and in 1909 it rose to the ninth state. This year the August freeze at Greeley has lowered her position again to the twelfth place. The acreage in 1910 was 64,000.

In money value per year her crop in fifteen years has grown from a little over a million dollars to an average, since 1903, of more than four millions of dollars, with the highest total in 1909

of $5,928,000. The production in bushels has risen from three and one-half millions to an average of between seven and eight, with the high point in 1909 of 10,400,000.

As to the future, more acres will be put in to potatoes, and great increases in production are to come from better methods. Better understanding of seed potatoes and the laws of productiveness are to be a big factor. Improved strains and improved varieties will count a great deal, and we are beginning the work of developing such strains and varieties.

It is calculated that improvements in varieties and seed stocks can workably affect a minimum increase in quality and value of five per cent., and associated with it will be an additional yield of at least as large an amount. If we figure only ten per cent. on a six million dollar crop, and another ten per cent. in possible betterments of methods, the economic prize to the state is well worth reaching out after. Colorado has been ambitious for her potato industry and its expansion, and liberal in her provision, that no industry be better served, and that the experience of all be gathered and made available to all, to the end that potato growing shall be nowhere on a higher plane of intelligence, service or profit.

With this brief general glimpse of the potato industry of Colorado, and its relations with the college, we will plunge into a detailed account of potato growing and its problems, designed for the use of Colorado growers, of those interested in the crop commercially, and of high schools in potato districts. To it is appended a report of field work in 1910.

INTRODUCTION.

THE POTATO CROP.

More weight of food is produced by potatoes than by any other crop of the world. In number of bushels the potato far exceeds any of the great cereal crops of the world; wheat or corn or the rice of the Orient are far behind it in total production.

Per Capita Consumption.—While the potato is universally used among American people, the consumption per capita is notably less than in Europe. According to the statistics of the Department of Agriculture, the crop of the United States is not far either way from 300,000,000 bushels per year, or 3½ bushels per capita. Germany, a country that is a little more than twice as large as Colorado, produces 1,600,000,000 bushels, or from five to six times as many as the whole United States. The people of Germany, as well as the people of Ireland, in place of using 3½ bushels of potatoes per year, consume twenty-five bushels per capita.

Where Grown.—By far the larger part of the potatoes of the United States is grown in a few of the *northern* states. In fact Maine, New York, Pennsylvania, Michigan, Wisconsin, and Minnesota produced half of the immense crop of 1909.

While Colorado is the 10th or 11th state in production of potatoes, she is one of the leaders in the investigation and promotion of the industry. A little study of potato prices and possibilities of potato growing will show why Colorado is one of the leaders in this work.

TABLE 1.—Average Yield of Potatoes per Acre, in bushels.
(From U. S. Dept. of Agriculture, Yearbook.)

Year:	1904	1905	1906	1907	1908	1909	Average
Nebraska	120	93	87	73	78	78	88
Wisconsin	126	68	97	91	80	102	94
Michigan	121	67	95	90	72	105	91
Iowa	136	80	95	85	80	89	94
Minnesota	102	87	92	101	76	115	95
*New York	93	70	105	98	82	120	94
Colorado	159	160	125	150	125	160	146

TABLE 2.—Average Farm Value of Potatoes per Acre, on Dec. 1.
(From U. S. Dept. of Agriculture, Yearbook.)

Year:	1904	1905	1906	1907	1908	1909	Average
Michigan	$35.09	$37.52	$32.36	$40.50	$41.76	$36.75	$37.33
Minnesota	29.58	41.00	34.04	41.41	42.46	42.24	38.45
Wisconsin	35.28	42.16	29.10	40.95	48.00	38.39	38.96
Nebraska	31.20	34.41	45.25	51.10	42.90	46.80	41.94
Iowa	38.08	39.20	40.85	46.75	48.00	48.95	43.63
*New York	50.22	49.00	51.45	55.86	61.50	60.00	54.67
Colorado	58.83	91.20	56.25	99.00	75.00	91.20	78.58

*These states are direct competitors of Colorado, with the exception of New York, whose great acreage gives the state a large influence in the potato market of the United States. Maine alone, among the great potato producing states, exceeds Colorado in production per acre, but Maine's geographical position and large costs of production are such as to exert little influence on the Colorado potato industry.

Colorado Yields Compared With Other States.—One half more potatoes per acre are shown by Table 1, to be produced annually in Colorado than in any of the great potato states mentioned. These averages cover the whole state, not only the irrigated parts but a large area in eastern Colorado that does not, and never can be expected to produce the highest yields.

Money Value Per Acre.—Yields per acre do not necessarily mean high money values. Table 2 shows that Colorado not only produces a high average yield of potatoes, but that the value per acre is also more than in any of the states mentioned.

Net Profit.—Again, yields per acre, or values per acre, do not always mean net gains. The cost of growing must be taken into consideration as well as the gross income. In Colorado, by far the greater proportion of the crop is grown by irrigation and it may be claimed that this increases the cost. This is true, but the cost is much more than offset by the fact that practically no fertilizer for growing this crop in Colorado is needed, and that in a large part of the state no spraying is done for either fungus diseases or insect pests. In fact, these two items alone, in many cases, cost more per acre in some of the great potato producing states than the total cost of production in Colorado.

Native Home of the Potato.—While the potato is a native of the tropics, its habitat is at a high altitude. By far the greater part of the potatoes grown in the United States are produced along the northern border and few are produced in the south.

Potato Prices, North and South.—Last year the price of potatoes in Wisconsin, Michigan, New York and other northern states was less than fifty cents per bushel when potatoes were from $1.00 to $1.10 per bushel in South Carolina, Georgia, Florida and Texas.

Colorado's Favored Position.—Colorado is practically half way between the producing and consuming regions. This gives the growers a great advantage over their competitors in these high priced markets. The northern states have the cool climate which adapts them to potato growing, because of their high latitude. Colorado, because of its high altitude, has practically the same summer climate as far as temperature goes.

Dryness and Sunshine.—The northern states have, with their cool climate, a tendency toward humidity and cloudiness that Colorado does not have, and as sunshine is a most essential thing in plant growth, Colorado has a considerable advantage in this respect.

OUR TERRITORY AND ADVANTAGES SUMMARIZED.

Northeastern Colorado.—Until the present time, the major part of the potato production of the state is confined to the Greeley district, which embraces approximately 250,000 acres and will be nearly doubled by ditches under construction. East along the Platte, including the country about Fort Morgan, Sterling and Julesburg, potatoes are being grown more than formerly, and the dry land growers of these regions are taking greater interest in this crop.

The San Luis Valley.—This valley includes an area of 3,100,000 acres of land, which is largely adapted to potato growing and has untold possibilities. In fact if one-tenth of the area of the San Luis Valley were to be planted in potatoes, and should produce 10,000 pounds per acre (which is not a large yield for this district), the valley would produce one-fifth of the present potato crop of the United States.

The Grand, Eagle, and Crystal River Regions, known as the Carbondale and Eagle district, contain many thousand acres of land admirably adapted to potato growing but not yet fully developed.

The Uncompahgre and North Fork Valleys comprise more than one hundred thousand acres of land, the most of which is adapted to the growth of this plant.

Archuleta, Montezuma, Dolores, La Plata, and San Miguel Counties, in the southwestern part of the State, have large areas that are well adapted to this crop but not yet developed to any great extent owing to a lack of direct transportation.

Rio Blanco, Routt and Grand Counties have remained largely undeveloped for the same reason as the last section, although they have many thousand acres as well adapted to the growth of this crop as those districts that have become famous.

A Summary of Advantages: Colorado climate is ideal for potato production, eighty-five per cent. of the days in the year being fair.

Colorado soils need no fertilizer for the growing of this crop out side of the established rotations.

Colorado's geographical position gives a big saving of time and freight in reaching the high priced markets of the United States.

Few of the many potato diseases trouble Colorado growers.

Colorado's production per acre, including a large per cent. of unirrigated lands, is much greater than that of the great potato producing states with which we compete, and the value of the crop per acre is about double that of those states.

The money received for Colorado potatoes is largely net gain to the State as very little money is sent out for fertilizers, etc.

The potato crop at present brings to the growers approximately $6,000,000 a year. Colorado has undeveloped lands enough to make the total output several times what it is at present.

THE BOTANY OF THE POTATO.

Solanum Tuberosum, is the botanical name for the common potato of commerce. It is closely related to the tobacco and tomato and to the nightshade, the egg-plant and the buffalo-bur. Other species of tuber-bearing Solanums have been domesticated in the hope of finding a potato equally as good as *tuberosum,* and one that would be more resistant to fungus diseases. Among these are *Commersonii, Maglia,* and *Jamesii,* the last being a native of the mountains of southwestern Colorado. None of these species have ever become valuable as a source of human food.

What Is a Potato?—Botanically, the potato is a tuber or enlargement in a stem or branch, normally under ground, but sometimes above, even in upper branches when disease or accident has interfered with the formation of tubers below ground. Not infrequently growers speak of the potato as a root, or growth from the root. The tuber has no connection with the root system of the plant. This structure of the potato may be best observed by examining the the plant about the time the blossoms are forming. If the plant is carefully dug, the small stems will be observed growing from the main stem of the potato above the seed piece from which the plant came.

Tuber Stems Vary greatly in length with the varieties. The stem of the Pearl is short, and the tubers are set close in around the old seed piece. The stems and tubers of a Rural New Yorker go more deeply into the soil. The Peachblow has not only a long underground stem, but often the stem continues through the first tuber, so as to have two or even three tubers on the same stem.

Potatoes from Seed.—While the plant is usually reproduced by cuttings of the tuber, it may be reproduced from true seed, as it undoubtedly is propagated in part under wild conditions. Many of our best varieties of potatoes, however, never produce seed balls, nor even perfect blossoms. (For a discussion of this point see Bulletin No. 176.)

The Function and Development of the Tuber.—The plant food, elaborated by the plant during the summer, is deposited in the tuber for the use of coming generations of plants, and a very large part of this food is deposited during the last weeks of the plants' growth.*

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*For an explanation of tuber structure see Quality of Potatoes herein.

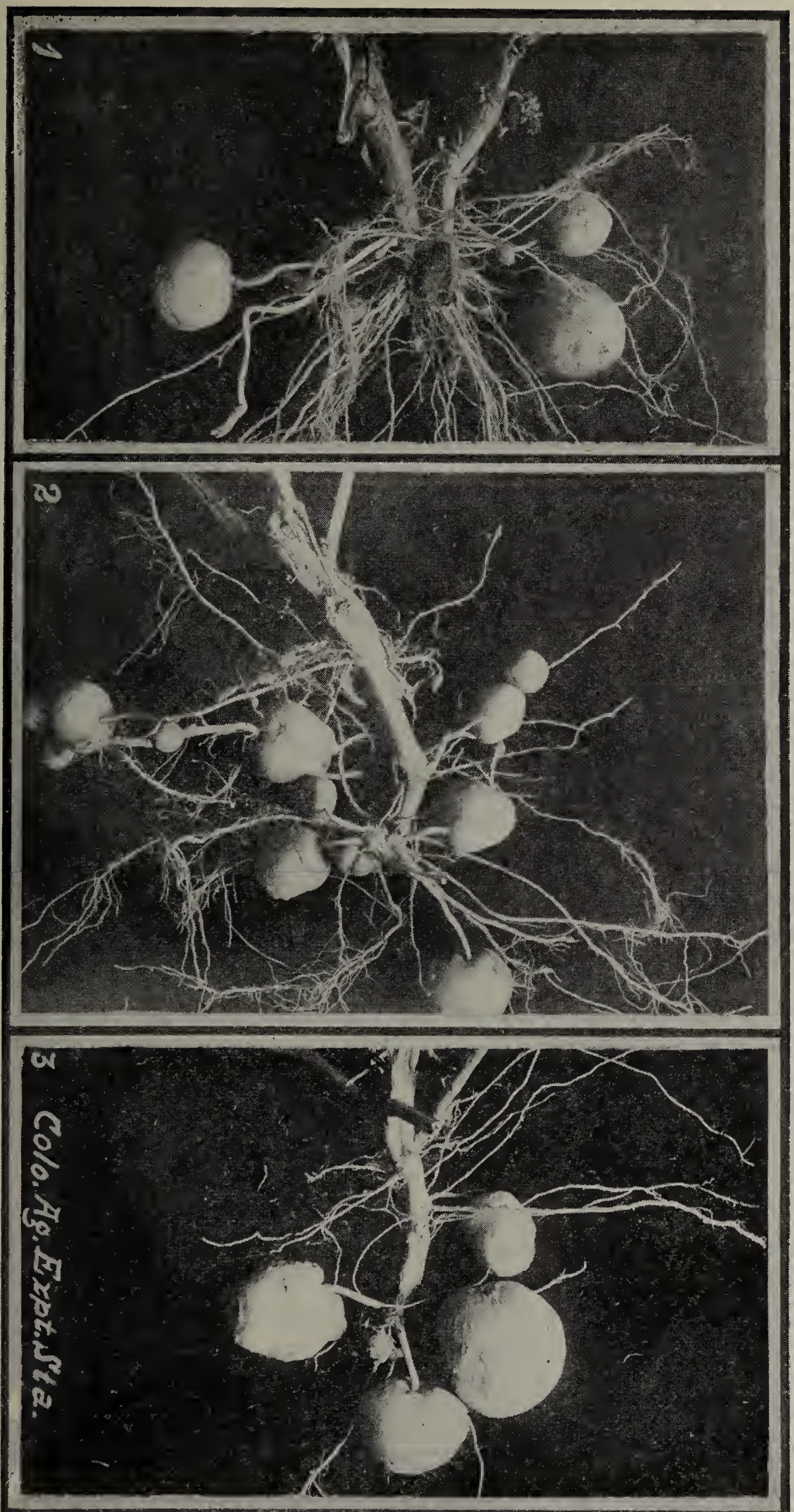

PLATE III.—HABITS OF GROWTH

1. Rural. 2. Peachblow. 3. Pearl

It has been found in several experimnets that where the ground and plants are in good condition when the tubers have set, that a fair yield of tubers may be obtained, even though the top soil be dry so that little more plant food could be taken from the soil. This is an important point, in our irrigated districts, as we believe that entirely too much water is ordinarily given after the tuber-forming season of growth. We believe that where the soil is in fairly moist condition at the bottom of the hills when the tubers are one-third grown, that the yield will be practically as great if no more water is given, as if another thorough irrigation is applied. Those plants that die back to the ground each winter as the asparagus, rhubarb and lily take care of the plant food by storing it in the underground parts. This is also true of the potato except that the food is stored in a different part of the plant. If the potato stem or leaf be examined during the latter part of the season, considerable quantities of starch will be found in the tissue. After the tuber begins to form, this starch is rapidly transferred to the tubers. In a field at Greeley in 1908 four plots were staked out by us, each of which contained 1/100 of an acre and were as nearly uniform as possible. The first of these plots was dug August 25. At this time a few of the tubers had reached the size of six or seven ounces. The plants were in good condition of growth and the soil moderately moist. The tubers dug weighed seventy pounds, or seven thousand pounds per acre. Nine days later the second plot was dug. In the meantime the tubers had very materially increased in size so that many of them weighed more than one pound. The total weight of the plot was one hundred fifty pounds or 15,000 pounds per acre. One week later the next plot was dug, which gave 170 pounds, or 17,000 pounds per acre. If the first plot had been dug two or three days earlier and the second plot two or three days later it would have been found that by far the larger part of the total tuber growth was made in two weeks.

POTATOES MIXED IN THE HILL.

The Botanist and the Farmer.—The botanist knows that potatoes cross or mix in the seed, and not in the tuber. The grower knows, as an actual fact, that he finds different colors and kinds of potatoes in the same hill from the same seed piece, and he often vows that the botanist is a theorist.

Both Are Right.—There is no occasion for bad blood on the subject. There is the highest authority that both are right. Just as Albinos are born in human families, or as peaches and apples sometimes have limbs whose fruit varies from that of the rest of the tree, so white potatoes come in purple hills, or purple in white hills, or round ones among long tubers, by natural variation, or coming up of diverse inheritance.

The Origin of Many Varieties.—By bud variation White Pearl potatoes came from Blue Victors,* White Ohios from Red Early Ohios, and Red Peachblows from the old spotted Jersey Peachblow. Thus, of the above Colorado standard varieties, three came "mixed in the hill," although they did not mix there, and only our Rural came to be what it is without this factor. The Rural came direct from the seed ball and so did the regular Early Ohio—the latter a cross between the Hebron and the Peachblow—"mixed," or crossed in the seed ball.

HISTORY OF THE POTATO IN COMMERCE.

The Potato Was Discovered in 1532 by the expedition of Pizarro near Quito in Peru, where it was cultivated at an elevation, they thought, greater than the line of eternal snow in Europe, and was found growing wild still higher above the tilled lands of the Incas.

Spain, Italy, and France soon saw specimens of the tubers, first as botanical curiosities and then as a possible source of food for peasants. In 1586 the plant was brought to the attention of Queen Elizabeth of England. As late as 1719 the potato was not listed in a garden manual in England which purported to be complete. Somewhat over 200 years ago, interest had been shown by English landlords in the growing of potatoes for food for their Irish tenantry and the crop soon thereafter became important throughout Europe.

Germany, Russia, Austria, and France, in the order named, lead the world in the total production of potatoes. Their use as food for stock, as a source of alcohol for mechanical and household purposes, and as a source of starch for cloth makers and laundries, is now a great factor in the consumption of the potato.

Why Grown.—Climate and the cheapness of the potato as a food (with no process of manufacture needed) among people where cheapness is desired or imperative, together with the small knowledge required for moderate success with the crop, have been the chief factors in the extensions of potato culture. The appreciation of good potatoes as a staple food is a later factor.

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*In a field of White Pearls in 1908 we found in different hills two potatoes which had small purple spots covering eyes. These tubers were planted that winter in the college greenhouse, the purple and white eyes separately. The potatoes grown from these pieces came true in color to the color of the eyes planted, and they were planted in the field at Greeley in 1909, again coming true in color except for some white streaks on the purple variety. This stock was planted in 1910 at Del Norte and again came true each to its color. These are the "White-Eye Pearls," and "Purple-Eye Pearls," noted in the Del Norte Tables.

Corn, Tobacco and Tomatoes have remained to a great degree American crops, the tomato having been the last to enter use on a commercial scale, and that almost entirely in America. Cotton came to us and we lead the world in its production. It has been the reverse with the potato. South America, its home, produces less in total than Colorado, and the potato crop of the United States is insignificant as compared with that of Europe.

The Potato as Freight is important, because it is better economy to grow it in the north, or in the high altitude districts, and transport it south, than to grow it in the uncongenial climate of the south. The weight of the potato crop of the world is nearly half more than the leading grains—wheat or corn—and nearly three times the weight of the world's rice crop. The average crop, in tons per acre, of potatos in Colorado, is about six times that of grain. Fully as large a per cent. of the potato crop is shipped by rail as of wheat or corn, and potatoes pay a higher freight rate.

QUALITY IN POTATOES.

Table Quality in potatoes is an important factor in the development of the industry in the United States. All but a very small per cent. of the potatoes grown in this country are used for human food. When the quality is high the amount consumed per capita is considerably more than in years when the quality is low. Attention on the part of the growers to producing smooth, white fleshed, mealy tubers will increase the per capita rate of consumption.

What Constitutes Quality.—From the American standpoint, the popularity of the potato as a food depends for the most part upon its starch content, because in the United States the consumer demands a mealy potato. In continental Europe, France in particular, a soggy potato is preferred. The amounts of starch and other ingredients vary with the variety and also with the conditions under which the potatoes grow. C. F. Langworthy in the Yearbook of Agriculture gives the average chemical analysis as follows: "The edible portion of a potato is 78.3% water, 2.2% protein, .1% fat, 18.4% carbohydrates (principally starch), 1% ash or mineral matter."

A Thin Cross Section of a potato held to the light will show that the tissue is composed of several different layers or areas. The outside *skin* corresponds to the bark of the stem; inside the bark is the sap wood or vascular tissue which in the potato is known as the *cortical layer.* This is readily distinguished as a layer from one-eighth to one-half inch thick just under the skin and is bounded by a dark line of *fibro-vascular* tissue. Inside this line is another area that is ordinarily of about the same density as the cortical, known

as the *external medullary* area. This corresponds to the heart wood of the stem. Inside this area is an irregular tract of much more transparent tissue. This is called the *internal medullary* area and corresponds to the pith wood of the stem.

Proportions of Each Layer.—The French chemists, Coudon and Bussard, give these different areas that make up the body of the potato in the following percentages, as average, by weight:

Envelope or skin........ 8.79%
Cortical layer 36.19%
External medullary area........ 34.17%
Internal medullary area........ 14.96%

Chemical Composition of Each Layer.—The following table taken from their analysis shows the relative amounts of starch and nitrogenous matter in these different areas:

	Starch per cent.	Nitrogenous matter	Water per cent.
Cortical layer and skin.......	19.42	1.99	74.79
External medullary area.....	16.29	2.14	77.44
Internal medullary area......	11.70	2.31	82.16

Thick Cortical Best.—As will be seen the cortical layer is richer in starch than the outer medullary and both of these are very much richer than the pith or inner medullary area. Consequently the potato with the thickest cortical layer contains the greatest amount of starch. It is also true in this table that the per cent. of water and total nitrogenous matter increases from the outside to the center of the potato. This analysis was made from three European varieties which were bred for nitrogen content rather than for starch. Analyses made at the same time, however, show that while the total nitrogen increases from outside to center, the per cent. of proteid nitrogen or that which is digestible, to the total nitrogen decreases from the outside to the center.*

*E. M. East, in a bulletin published by the Illinois Experiment Station, makes the following observations in regard to physical structure and quality in potatoes.

"Microscopic examination of the structure of the potato bears out the chemical analysis of the different zones.

"The cortical layer, below the first few layers of cells which are removed with the skin, shows a markedly larger amount of starch in the cell than does the internal medullary layer. The starch content of the external medullary layer is also greater than that of the internal. The grains of starch in the cortical and external medullary layer besides existing in greater number per cell are generally of larger average size. The paucity of starch in the internal medullary area causes the cells to be only partially filled with the cooked starch and the cell walls are scarcely ever ruptured. In the cortical layer, on the other hand, the amount of starch is such that in the swelling due to cooking, the cells are filled completely and many of them ruptured causing the mealy appearance so much desired by the consumer.

"It is quite evident then that potatoes having so far as possible a homogeneous flesh and containing as large amount as possible of cortical and outer medullary layers in proportion to the inner medullary layer, should be the finest quality."

Where there is a shortage of starch in the cells the cell walls retain their structure and the water contained in the potato is not all taken up by the starch with a result that the potato is soggy, and not mealy.

A Microscopic Examination of different potatoes shows that the starch granules differ in size with the different varieties. In comparing Snowflake with Pearl it is found that while the Snowflake has a large quantity of starch granules the average is much smaller than in the Pearl. The greater number apparently makes up in this case for the size of the granules so that ordinarily comparatively little difference is found in the mealiness of these two varieties when each is properly grown. In general, it may be said that the Snowflake is finer grained when cooked than the Pearl and very much finer than the Peachblow, probably owing to the difference in the size of the starch granules.

The Degree of Ripeness of the tuber has much to do with its chemical constituents. The unripe potato is usually richer in nitrogen but decidedly deficient in starch content. A high starch content does not necessarily mean a good flavored potato. The German potatoes that are grown for alcohol and starch making, are richer in starch than the better varieties that are used for culinary purposes, but are decidedly deficient in flavor.

What Causes Flavor in a potato is not known. There is apparently the same difference in varieties of potatoes in regard to flavor as with fruits, only to a lesser degree. Freedom from disease of any kind, absence from exposure to light, and mechanical texture, are known to be large factors in potato flavor.

Market Standards are largely set by size and appearance of the tubers. It has been found that a tuber weighing from eight to twelve ounces is the most desirable both from the standpoint of economy in handling and cooking and from the standpoint of quality. Very large tubers are apt to be coarse in texture and frequently hollow in the center as the result of the breaking down of the pith cells. This tendency toward being hollow is a varietal characteristic, but all potatoes are more or less subject to it when overgrown. The large potato is also more apt to be deep eyed than the medium sized tuber.

Loss in Paring.—Few people realize the loss of food material in paring the small, rough or deep eyed potato. The following table shows comparative losses from paring different sized tubers:

	Original weight	Pared weight	Loss	Loss %
Smooth	10½ oz.	8⅞ oz.	1⅝ oz.	15%
Smooth	6¼ oz.	5 oz.	1¼ oz.	20%
Smooth	3¾ oz.	2⅞ oz.	⅞ oz.	24%
Rough	7¾ oz.	5¾ oz.	2 oz.	26%*

* In cracked, very rough, or deeply flea-marked potatoes we find a 40% loss in paring often unavoidable; and in extreme cases this loss may run to 75%.

Loss of Food Value.—The loss in weight is not the only serious part of paring away the tuber. As has been shown, the food value of the area of the potato just beneath the skin is much greater than the center of the potato. Where potatoes are particularly rough it will be seen that not only is one-fourth of the weight of the potato removed but considerably more than one-fourth of the real nutriment of the tuber is lost, and that of the best quality.

HOW TO DETERMINE GOOD POTATOES ON THE MARKET.

Color no Guide.—It is not uncommon to hear consumers say they always use certain colored potatoes as they have found them to be better in quality than some other color. So far as has been determined, there is absolutely no correlation between color and quality. Certain markets demand a certain colored potato to the exclusion of all others simply because they have been educated to that color. In fact, if it were desirable to do so, it would be possible by breeding to change the color of nearly any of our potatoes from white to red or the opposite.

The Appearance of the Skin indicates the quality of the potato. When the skin of a given variety is smooth and more or less transparent with what is called a "baby skin," and the potato has a soft spongy appearance, it is usually deficient in starch and is apt to be soggy. This condition is usually the result of immaturity of the tuber. The tuber should have a russeted appearance due to crackled skin; and it is usually considered a mark of good quality when the potato is well covered with lenticels. The degree of russeting differs with varieties but with a given variety the more russeted potatoes are the better in quality.*

The Amount of Irrigation given to the plants has much to do with the quality. It has been found in Colorado that soils that are well drained, and particularly those soils which are newly broken from prairie or sage brush, usually give better quality than older soils that are more retentive of moisture. Where irrigation is stopped early to allow the potato to mature in a dry soil the quality is greatly improved over those that mature in a wet soil.

Proper Irrigation a Help to Quality.—The growth of the tuber may be controlled under irrigation so as to produce the highest

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*Gilmore of the Cornell Experiment Station found that with most potatoes those growing close to the surface were not so good quality as those grown deeper in the soil, doubtless because the deep grown tubers set first and had a longer season with greater ripeness. It has been found also that where plants reached a natural maturity before the vines were killed from disease or frost, the tubers were superior in quality to those from plants destroyed previous to this condition.

quality possible, as water may be given as needed, and in Colorado diseases rarely prevent the plant from reaching full maturity before frost. Where early irrigation can be practiced, and tubers can be set early, they reach fuller maturity and finer quality. The naturally dry climate of our State makes it possible in most seasons to mature potatoes in dry soil.

VARIETIES.

Success or failure in potato growing depends most vitally upon selection of the right variety.

The White Pearl.—This variety, known as Peerless in the eastern states, is adapted to more conditions and soils in Colorado than any of the others that have been grown. At least two-thirds of the potatoes grown in Colorado are of this variety. It is a standard at Greeley and in the San Luis Valley and does well on the West Slope and on dry land farms. The Pearl, in season, is neither early nor late. As this potato is the most common one grown in Colorado we shall use it more or less as a standard by which to compare other varieties.

The Rural New Yorker No. 2.—This standard variety, the leading sort in the United States, is ordinarily a little smoother and more uniform in size and shape than the Pearl, and is from a week to ten days later in season. It is somewhat more subject to diseases other than early blight, and is influenced by adverse weather conditions more than the Pearl. In the Uncompahgre district it seems to be even better adapted to the climatic conditions than the Pearl and gives fully as large yields.

The Peachblow, wrongly known as Red or White McClure, is the potato with which Carbondale has made her name as a potato growing district. This potato is fairly uniform in size and quality but seems to be adapted only to the best environment. At Greeley, this variety quickly degenerates and changes its color and characteristics. It is the excellence of Carbondale conditions for potato growing and not any particular variety that has made the region famous.

The Ohio Family, the leading early potatoes of the United States, are characterized by high quality, extreme earliness, low vitality, and moderate or low yields, with a tendency to poor shape. To this family, all much alike, belong the Adriondack, Six Weeks, Acme, and White Ohio.

Other Varieties.—*The Irish Cobbler is a strong competitor of the Ohios, and is already displacing them to some extent in Colorado. The Charles Downing, a close relative of the Snowflake, is of excellent quality and is desirable in some localities for mid sea-

*See **Early Potatoes** for comments on the Cobbler.

son market. In the San Luis Valley, a potato known as Monroe County Prize, has been grown for a long time and is a desirable, long potato. The Russet, grown in the Carbondale district, is a high quality, early, long potato of great promise in our mountains. See *Field Experimentation* for the undesirability of any other sorts than those mentioned here.

SOILS.

What is a Potato Soil.—In a very general way this question may be answered by saying that potato soil is deep sandy loam, with some sort of under drainage. Potato growing in the Greeley district is on soils that range from light sand to heavy clay. The underlying stratum of most of this district is coarse gravel at a depth of from one to several feet. Some of their best lands are deep medium sandy loams underlaid with porous white clay either above gravel or in connection with a good slope.*

The Character of the Subsoil appears to be more important than the character of the surface soil. In fact some of the heavier soils of the district where underlaid by gravel at two to five feet, are among the best of the potato sections of the district.

In the San Luis Valley, which is an old lake bed, there are considerable areas that are inclined to be gravelly, although the soils there vary from light sand with gravel subsoil to heavy clay or adobe. Some of the best potato soils are those of the river bottoms, composed of river sedimentation and wash from the surrounding hills.

On the West Slope the deep red sand stone soils are among the best adapted to potato growing. The gray wash or till soils from the hills are also good. The Carbondale district and some of the mesas of the Uncompahgre and North Fork Valleys are of the red sand stone character and are particularly adapted to this crop.

Adobe Soils in these districts are often used for potatoes but with constant risk of bad seasons and damage from soil diseases, owing to the tendency of these soils to become puddled. Greater care is necessary in cultivation and in irrigation, and even where the greatest care is used rains frequently compact the soil so as to stop tuber formation. This is particularly true of the soils on the college farm.

Potatoes Unsuccessful on Most Heavy Soils.—We have planted potatoes on this kind of soil at Fort Collins for the past five years. The cultural methods used have been similar to those which give

*Their most common soil is that which is designated by the Government Soil Survey as the Colorado fine sand. Other soils of the same district are those known as the Billings loam, Colorado sand, and Billings clay loam. The soils of the river bottom known as the Laurel sand loam, also grow potatoes.

success in the Greeley district. All these crops but one have been, practically, failures.*

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*__The first year__ the cultivation was largely with a shallow cultivator. While the soil was kept loose on the top it was not loosened at a sufficient depth to affect the tubers, and almost total failure resulted.

The second year about two acres were planted on the west college farm and cultivation was given soon after planting. In this cultivation the soil was loosened to a depth below the plowing, or from nine to twelve inches. A second cultivation of the same character was given soon after the plants appeared above the ground. No more cultivating was done but the land was ditched twice with a shovel plow which was equivalent to at least one cultivation. Although this soil is decidedly heavy, these cultivations loosened up the soil below where the tubers were formed. No heavy rains occurred to pack this soil and at digging time the soil was loose as deep as the tubers were set. This year a good crop was secured.

The third year the same ground was again planted to potatoes, making it the second crop after alfalfa, and another plot was planted on freshly broken alfalfa land. The same kind of cultivation was given and the soil kept in the best of condition till the middle of July. At this time the potato tops were sufficiently large to cover the ground and the tubers had reached the size of from one-half to an inch in diameter. Heavy rains following for one week packed the soil to such a condition that a spade was required to dig into the hills. After this packing of the soil there was practically no growth of tubers and although a month elapsed before frost came, and there was no disease of importance to be found, the tubers did not reach marketable size.

The same season a plot of nearly an acre was planted about three weeks earlier than the main crop. Heavy rains followed this planting and caused the soil to become packed and sticky. A good stand of plants was secured but most of the plants became diseased soon after pricking through the ground, and no amount of cultivating could loosen this soil sufficiently to even make a good growth of vines. Almost no tubers were secured from these plots.

The fourth year the same plots were planted again with an additional plot of freshly broken alfalfa land. This year's experience was to a great extent similar to the year previous. Dry weather prevailed during the early part of the season which gave the plants a good start in loose soil; later in the season heavy rains packed the soil about the time that tuber growth commenced. These plants were comparatively free from disease but made very little tuber growth although the vines were of average size.

What tubers were formed in the compact soils during these three years of failures on the college farm, were distorted in form so as not to follow the type of the varieties.

The fifth season (1910) potatoes were planted on another plot of freshly broken alfalfa, with soil similar to the other place. This season heavy rains followed the plowing even before the potatoes were planted. In order to overcome the packing of the soil by the rains a deep cultivation was given this soil before planting. This went far toward putting the soil in better condition but tended toward drying the soil more than was good for the plants. A fair stand of plants was secured, however, and growth was about normal until the latter part of the season when heavy rains again offset the work of deep cultivation. Some marketable tubers were secured but as a whole the crop was a failure.

This experience is not only true of the plots on the college farm, but is the experience of growers for the past twenty years in a large part of the districts along the foothills of the East Slope, and in the Arkansas Valley.

We believe that the character of the soil in regard to being **packed by rains** in addition to their becoming sticky and so excluding air, during

GETTING LAND READY FOR POTATOES.

Preparing Raw Soils.—It is better for the grower to break raw lands during the summer of the year previous to growing the crop. This puts the soil in better condition for taking and holding water and for culture than where the raw soil is broken in the spring before planting. New land in Colorado seldom produces the maximum yield of potatoes, because it is deficient in vegetable matter and therefore in nitrogen, while the physical condition of the soil can never be gotten in the best shape the first year.

The Best Crop for Subduing Raw Lands in Colorado is undoubtedly the potato, even for soils really too heavy for this plant. No crop puts the land in so good condition for the succeeding crop, or for leveling and getting the land into alfalfa. The continuous cultivation of the potato crop, the irrigation, and then the digging in the fall (which is a far better mulch than a fall plowing), leave an exceedingly favorable physical and chemical condition of the soil.

Various Rotations.—In northern Colorado the most common rotation is, potatoes two years, followed by grain as a nurse crop for alfalfa, then alfalfa as a hay crop two years—a five year rotation. Where diseases have interfered with the potato crop, this is sometimes changed to potatoes one year, grain one year, potatoes one year, grain and alfalfa one year, alfalfa two years, then back to potatoes. Where the canning of peas has become an industry, peas have been grown between the two potato years in the place of grains. On the west slope the rotation for the most part is similar to that in northern Colorado. Sugar beets are often used in place of the second year of potatoes.

In the San Luis Valley the rotation is largely potatoes one year, peas one year, grain one year.

Alfalfa, Peas or Clover used in rotation prepares the land for potatoes by improving its physical condition and furnishing the necessary nitrogen. Experiments made by Paddock and Rolfs in the Greeley district showed that the use of a commercial fertilizer

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the middle of the season, is largely accountable for failures to grow crops in these districts. These soils for the most part are not only heavy at the surface but are underlaid by a stratum of almost impervious clay. In the Greeley district even the heavy soils are for the most part underlaid by a gravel stratum which makes good drainage and which appears to prevent the packing of the soil. At almost no time in our experience in growing potatoes at Fort Collins, has there been a season when it was possible to dig into the ridge where the potato plants were growing, with the naked hand. At Greeley it is usually not difficult to dig the potatoes with the naked hand even where they are from six to eight inches beneath the surface. This, we believe, in a great measure accounts for the differences in soils as to their ability to grow potatoes. However, it is found that in the high altitudes and in some places of the West Slope potatoes are grown in soils that are apparently heavier than that of the college farm.

did not materially increase the yield in potatoes and consequently that the expense was not justified. Where manure is obtainable, the yield of all crops for several years is increased very materially. Where potatoes are grown on feeding or dairy farms the manure has very materially increased the yearly total production per acre.

The Breaking of Alfalfa.—Previous to 1886 it was thought that alfalfa could not be broken for potatoes. Up to that time the yield of potatoes in the Greeley district had been gradually decreasing; since that time much progress has been made in the methods of breaking and handling alfalfa land, and the yield of potatoes per acre has shown a great increase. The rotating or small harrow and the two-way plow with five and six horse hitches mark the highest advancement in alfalfa breaking.

Turning Alfalfa Under.—On heavy soil, plowed and planted late, it is not uncommon to allow alfalfa to grow in the spring to a height of ten or even eighteen inches at the last before plowing. This alfalfa is broken by plowing not less than eight inches deep, with a broad or alfalfa shear longer than the furrow width and flattened to sever the alfalfa root before the moldboard lifts the soil.

Heading Alfalfa is a system of great merit growing in use. The land is plowed in the fall or early spring as shallow as it is possible to cut the alfalfa roots below the crown. Then the harrow follows the plow and brings the severed alfalfa crowns to the surface so that they may be dried out and killed. After the alfalfa crowns are dry and dead, a second plowing is given the land, this time going down eight inches or so. Alfalfa *roots* never send up sprouts so that if the root is cut below the crown and the upper portion is killed ,no further trouble will be experienced. The great trouble with planting on alfalfa ground has been that after the alfalfa is turned over, sprouts start from the *crown* and continue to grow during the season. See *Cultivation*.

Clover and Peas used in place of alfalfa give no trouble of this sort but are not equal in fertilizing value, though the soil is left by either in very fine condition.

Irrigating Before Plowing.—While in northern Colorado there is usually sufficient rain to make it possible to plow during May without previous irrigation, still where water is at hand, both at Greeley and in other parts of the state, where the rainfall is less, it is desirable to irrigate before or after planting, and this is best done before plowing. In any case the plow should be immediately followed by the harrow.

The Smoothing Harrow.—The usual practice is to plow from morning until near noon, then unhitch and harrow what has been plowed in the forenoon before leaving the field. The same should be done in the afternoon. This harrowing establishes a soil mulch

and conserves the moisture which is needed to start the plant, and also warms the ground by preventing evaporation. Before planting, the soil should be leveled and thoroughly harrowed, or disked and harrowed so as to secure an even seed bed, fined to a depth of three or four inches.

EARLY POTATOES.

A Hill of Triumphs.

The Early Potato, a Small Plant.—It is impossible for an early potato to rival in production a larger later sort. An early potato of maximum yield is a seedsman's dream. However, we should study to secure from an early sort its maximum yield. This will be done by growing a large number of plants per acre.

A Good Start, above all things else, is the very foundation stone of early potato growing. This does not mean planting before ground and season are ready, but it does mean good soil fall plowed perhaps and everlastingly spring tilled, and ditching, irrigating and re-levelling before planting if the moisture condition be not right. Mellow surface with moisture both shallow and deep are absolutely required for success.

Close Planting both in the row and between the rows with slope enough to run water in small ditches, rich loose soil, special tools for narrow rows,* small footed and narrow tread horses or mules are needed for success with early potatoes.

Low Altitutde is not Essential to the growing of early potatoes. It is best done at from 5,000 to 7,000 feet elevation and such regions can supply the market soon after the Kaw Valley, while from 8,000 feet earlies can supply the market all of September. The cool summers, with slope and sunshine, make it possible to force potatoes with water, in ways impossible eleswhere without causing ruinous disease.

Potatoes in Orchards should be of early sorts so that the irrigation, tillage, and digging may be past in time for the new wood

*Funds permitting, in 1911 and 1912 we hope to work out special tools and methods for growing early potatoes in Colorado.

of the trees to mature well before winter; and early potatoes are one of the best crops that can be grown in an orchard.

Varieties of Early Potatoes.—The Ohio, White and Pink, leads all others of the United States in quantity and quality among truly early sorts. The Irish Cobbler is next and has spread from Maine west and south because it is a handsome white potato, free from the knots and cracks that disfigure the Ohio. It is nowhere (we have inquired and tested widely), good eating, except in our best mountain regions, where all potatoes are good. In Wisconsin, Kentucky, Nebraska, and on our own dry lands, it is inclined to be coarse grained, hard, and yellow fleshed. The Bliss Triumph, of which we have a white as well as a red sort, is the leading first

Potatoes in a Young Orchard

early of the south and is among our best earlies. The Russett and later the Downing, come ahead of maincrop and late sorts.

No First-Class Early potato exists. *The White Ohio,* with its fine appearance and perfect quality, would fill the bill, if it did not run to knots and cracks. *The Cobbler* would be everything desirable if it were good eating, and the same may be said of the White Bliss. We are striving to combine the desirable qualities in one potato. It is a long, difficult and uncertain task in which we are greatly interested.

SEED AND ITS TREATMENT.

Type and Source of Seed are as important as variety. Success also hinges upon such care of the seed as shall keep it in vigorous condition till put into the ground. A big yield of tubers must not

be expected when a poor stand of weak plants is obtained. (See in this bulletin the division on the subject of *Stands.*) For Greeley and the San Luis Valley, where potatoes tend to degenerate after two or three years, the best seed is secured from the dry lands of Colorado, Wisconsin or Minnesota or the unirrigated districts in the mountains. This seed, when planted in the Greeley district, produces the most desirable seed for the succeeding year.

Trueness to the Type of the variety in hand is an essential in selecting any kind of seed potatoes. While their previous history and other things* must be considered in determining the value of any lot of seed potatoes, still, examination for trueness to type, tells us what we can learn from the potatoes themselves, just as in buying a horse, examination of the animal is a part of any proper purchase, although other inquiries are not to be omitted.

Seed for the San Luis Valley.—In some parts of the valley there is trouble in securing good stands because of dry weather. In these places whole potatoes are usually planted. This makes it necessary to plant the small tubers. Where the tubers that go through a one and seven-eights screen at digging time are used for seed, the yield from year to year rapidly decreases, and the best practice is to change seed, securing that from the unirrigated lands of the State at least once in three or four years.

Seed for the West Slope.—In the West slope districts, potatoes may be used for seed year after year with little apparent deterioration in the vitality of the plants. In fact no change of seed has been made on some places at Carbondale since the potato growing industry was started thirty years ago.

The Best Home Grown Seed is secured by selecting the tubers from the field at digging time. This should be done from the best hills rather than by selecting the best individual tubers. The characters that are transmitted by the tuber planted, are more apt to follow the characters of the parent plant than of the individual uber. Therefore, we should look to the vitality, productiveness and trueness to type of the whole plant.

Hill Selection.—*The best method for securing seed is to go through the field at digging time with a fork and dig the plants that appear strongest and most productive. If the plant proves to be true to type and has the required number of tubers, with no scab or misshapen tubers, the better potatoes from the hill are saved for seed. If not, the tubers should be covered up to be dug later with the digger. Some skill and knowledge of the variety is necessary for this work. Where incompetent help is to be depended upon

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*See Bulletin 176.

*This has not been successful in the Greeley district. See Bulletin No. 176.

it is best for the grower to take three or four men with him so that the work may be readily directed. This way of securing potatoes is somewhat more expensive, but experiments by Goff of Wisconsin, Waid of Ohio, and results in Germany, as well as in Colorado, show it to be time well spent.

Buy Seed in the Fall.—It is a common practice for growers to defer buying seed till planting time in the spring. When this is done the grower ordinarily knows little if anything as to how these potatoes have been grown or stored. It would be better and cheaper if potatoes were secured at digging time so that the grower can know something of the growing and can make sure that these potatoes have been stored in the best possible manner to retain their vitality.

Storage of Seed.—There is an almost universal belief among growers that, if potatoes are chilled in storage, the vitality is decreased, but no actual evidence is at hand to prove this theory. In fact, our experiments tend to the contrary. In all those districts where snow falls before the ground freezes and lies until late in the spring so as to prevent deep freezing of the ground, so-called *volunteer potatoes* that have lived in the ground over winter, come up in the old fields. Where potatoes are left in the ground over winter without freezing, it will be found that tubers are to all intents and purposes in the same condition as at digging time in the fall. In these cases the tuber, while not frozen, must remain at near freezing point during the whole winter season. The condition of storage that most closely approximates this condition must be best so far as vitality of the tuber is concerned.

Sleeping Period.—Experiments have shown that the tubers must have a resting stage before they will grow. When mature potatoes are dug and immediately planted in the greenhouse, or southern grown potatoes are shipped to the north in the spring and planted, they will not grow till they have passed the resting period. The nearer dormant the tubers can be kept during the winter the better chance they have for making a perfect stand when planted in the spring. The danger from chilling is less than the danger to potatoes from heating.

Heating.—This is the generation of sufficient heat in the pits or cellars to lower the vitality, and often follows freezing. Of course if the tuber is frozen so as to cause decomposition of the tissues, or frozen sufficiently to change the starch to sugar, the vitality will be impaired, even if the buds are not killed.

*Greening of Seed.**—If the seed is kept dormant all winter

*During the spring of 1908, a study was made at the Experiment Station of the effects of leaving seed tubers exposed to the light. Several sacks were spread for a month on the ground in a barn where the

by cool storage, excessive spring sprouting may be prevented by greening. This is done by exposing the tubers to the light. The thinner the potatoes are spread out (certainly not over one foot deep) the better, and the oftener they are shoveled over, the better, which should be once a week, at least, for the last month. Of course it must be understood that the tubers are *not cut* previous to this treatment and are *not exposed* to heat and drying. Greening not only toughens the tissues and produces chlorophyll in the bark or skin, but largely destroys the spores of fungus diseases, and makes the seed pieces less liable to rot. For Colorado conditions, greening is preferable to treatment with corrosive sublimate or formalin, which treatments we do not recommend.

*Treatment for Scab.**—For four seasons, experiments have been made both at the Experiment Station and with growers in the Greeley district, with a treatment of seed for scab. In this treatment the seed was soaked two hours before being cut for planting in a solution of a pound of formalin to fifteen gallons of water. No beneficial results whatever were secured.

Cutting Seed.—In planting potatoes it should be remembered that we are not planting the seed but a *cutting* of the old plant. The question of the size of the cut piece is always before us. The bud with a very small piece of tissue may be taken from the tuber and made to produce a plant. It has been found, however, in various experiments that the yield of tubers increases with the size of the seed piece, up to a certain limit. The reason for this is that the new plant must start its growth from the stored plant food in the piece of potato until it has sufficient root system to take care of itself. If the seed piece is too small or becomes dried there is not sufficient plant food to push it along so as to make a vigorous plant: conversely, if there is more plant food in the piece than is essential for growing the plant the excess is wasted. It has been proven in numberless careful experiments that it pays to use pieces as large as two ounces.†

Two-Ounce Potatoes may be planted without cutting. Four ounce potatoes are best cut in two. In order to have the eyes

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strong light could reach them. These tubers were somewhat shriveled from being stored in a cellar where the temperature was higher than was desirable and where the air was too dry. Nearly all became green and many lost so much moisture as to be decidedly dry and toughened. At planting time the potatoes had started to grow but the sprouts were only from a quarter to a half inch in length and were green and tough enough to withstand handling. It was thought that the worst of these tubers were too badly dried out to germinate, so they were planted by themselves, but, to our surprise, nearly all produced healthy plants.

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*See **Potato Diseases** in this bulletin.

†See in this bulletin the subject of **Stands**.

evenly distributed, the potato should generally be cut legthwise first. Six ounce potatoes are usually cut first lengthwise, then twice crosswise of the tuber.*

Gauging the Cross Cut.—It is best to make the stem-end pieces larger than the bud-end pieces. With the Pearl, this will nearly always insure at least one eye or bud in each or the stem-end pieces.

Hand Cutting is the only practical way. A few potato cutting machines have been used, but these have never come into general use because machines cannot exercise discretion as to the size of pieces and the eyes contained in each.

Cutting Racks.—The rack most commonly used, and which is the most satisfactory, is like the one shown in Plate VI. This is a slatted, sloping-bottom bin, with a frame for holding a sack open and a knife set at the rear side of the sack holder. The advantage in this is that the potatoes, when scooped into the hopper, are always at the hand of the operator, and instead of holding the knife in the hand, both hands are available for work with the tubers. When one is accustomed to using this device, it is found to be much easier and faster than holding the knife in the hand.

The Cheapest Cutting Device is made by driving a case knife into the end of a piece of board so that the operator may push the tubers across the blade of the knife. Many prefer to push the potatoes in any case, and to drop them thus into the basket or sack.

Do Not Cut too far Ahead.—Potatoes are best not cut more than twenty-four to thirty-six hours previous to planting. If they are left for any considerable time, the loss of moisture is so great as to seriously affect the stand. Similarly, cut seed potatoes in dry, warm, or windy weather must be covered on the wagon with a canvas and must not be left in the field or in the planter to dry out. It is found that the seed works better in the planters when the cut surface is allowed to become slightly dried before putting into the machine.

Dusting Seed.—Many growers think that less disease occurs in the fields where the cut seed is treated with flowers of sulphur or air-slaked lime after cutting. Where this is done, a handful of sulphur or lime is scattered onto each basket of potatoes as fast as added to the sack or on the thin layer on the floor. This dries the cut surfaces so they are at least more readily separated and

*Many growers have thought that the "seed end" eyes were not so productive as or differed from the stem end eyes. We find, however, no difference in their value. At the College, in 1909, two sacks of Pearl potatoes were cut so that the eyes from the seed end, the middle and the base of the tubers could be planted separately. So far as the most careful observation could tell, there was no difference whatever, between the lots, either in time of coming up, the per cent. of stand, the time of maturing, or the yield of these plots.

Plate VI.—1. A Modern Cutter Box. 2. Irrigating: every other row. 3. Plowing alfalfa sod.

work better in the machines. It is claimed by some that this treatment reduces the rotting of the seed.*

PLANTING.

Machine Planters are universally used in Colorado. The chief reason for this is that hand planting would be too laborious and expensive to be profitable, but if hand planting were not too expensive, it would not be satisfactory as machines do much better work than could be accomplished by hand. With the planter, the soil is furrowed, the seed dropped in place, and covered, all within a space of three or four feet, so there is no opportunity for the drying effects of the atmosphere to injure the chance for the germination of the plants. Where the plow and hand dropping is used the soil is very liable to become dried, as the planted tuber is in most cases covered with dry soil.

Picker Planters.—The Aspinwall, Evans, Superior, and Eureka are common types of the picker planter, and while each is different in detail, and some have been more thoroughly tried out than others, they all do practically the same work, are all automatic, and only require one man for operation.

Non Picker Type.—The Robbins Planter feeds the seed by dropping from between the spokes of a horizontal wheel and requires a second man to correct the drop, so that in this case the accuracy of the planter depends on the accuracy of the operator.†

Depth of Planting.—No hard and fast rule can be laid down as to the depth to plant potatoes. Much depends upon the moisture and soil conditions, and slope of the land. Ordinarily, where the soil is in good condition so far as moisture is concerned, and danger of frost is passed, two or two and one-half inches beneath the surface level is sufficient depth, while on flat land, in good condition, potatoes are sometimes planted only one inch deep.‡ Where the soil is apt to dry out, or where planting in dry soil, it is necessary to go deep in order to insure moisture. Deep growing varieties do not need to be planted as deeply as more shallow kinds.

In the Higher Altitudes.—Where there is enough fall to keep water below the tuber bed and where the ground is apt to be touched with frost before the potatoes are dug in the fall, it is well to plant

*Any dust will do the same so far as drying the cut surface of the potato is concerned. Dry Bordeaux mixture was also tried, along with other materials, at the Experimental farm in the year of 1907. This mixture did not prove satisfactory, as the copper sulphate in the mixture tended to shrivel the potatoes and apparently decreased their vitality.

†See the subject of **Stands** in this bulletin, and the per cent. of stands obtained by different machines on the 1910 plots. Robbins planters were used at Greeley and Carbondale; Aspinwalls at Montrose and Parshall.

‡In speaking of depth of planting, it is understood that the depth below the surface is meant, and not depth below the planter ridge.

such shallow growing varieties as Pearl, as deep as four inches below the level.

Width of Rows.‡—With most growers of late potatoes the average distance is 38 inches. This gives room for the planter, cultivator, ditcher, and digger to be used without interfering with the growth of the plants.

The Distance Apart of the plants in the rows depends on the variety and the richness of the soil, and varies considerably in different parts of the State. At Greeley, the average distance in the row we find to be thirteen inches on alfalfa land, and where potatoes follow potatoes or a grain crop, the distance is fifteen inches. On the rich lands of the Western Slope, potatoes are planted as close as twelve inches or even eight inches apart in the row, especially for Rurals on alfalfa land.*

In Dryland Districts, the distances apart for potatoes is much greater, as the plants need more space from which to draw moisture. In this case from eighteen to twenty-four inches is close enough, the closer distance being for early sorts.

CULTIVATING.

Packing of the Soil by the horses' feet when planting is unavoidable on our heavier lands, thus leaving the soil in poor condition for holding moisture, and also for the growth of the tubers. These two things, and the tendency of heavy soils to exclude air, have brought about a system of cultivation, particularly in the Greeley district, that differs materially from potato cultivation in the east.

The Greeley System.—It was found that in order to loosen up the soil and also to kill the alfalfa, it was necessary to cultivate deeply soon after planting. Experience soon taught growers that this deep cultivation, not only killed the alfalfa, but to a large extent prevented the development of diseases by loosening and aerating the soil. Where irrigation is practiced, and particularly with heavy and flat lands, the aerating of the soil is one of the important features in growing this crop.

On Sandy Soils, in some districts of the state, the need for this deep cultivation is not so imperative, although we believe that in all soils in Colorado that are to be irrigated, some degree of this deep cultivation is beneficial, at least once.

Special Cultivators which do this work satisfactorily have been made for Colorado trade. These, while similar to the two horse

‡These distances are all given for the maincrop potatoes. See elsewhere in this bulletin a statement of this matter in relation to **Early Potatoes.**

*See in this bulletin reports of close planting at Del Norte, Carbondale and Greeley, and **Stands** herein.

PLATE VII.—CULTURAL OPERATIONS.—1. Furrowing. 2. Digging. 3. Cultivating. 4. Planting.

cultivators of the east, are made heavy enough to stand the pull of four big horses and the strain of four shovels penetrating the soil from eight to ten inches.

Cultivation is Begun within a week after planting, or before the sprouts have more than started, the planter having left a ridge which may be followed without difficulty. The cultivator shovels are four inches wide by fourteen inches long, and are moulded and adjusted so as to throw the soil toward the row, and the inside shovels are run so close as almost to throw out the seed.

The Ridge and the Harrow.—After the cultivator is used, the soil is left with a considerable ridge over the row and a depression between the rows. This starts the work of ditching and provides drainage so that heavy rains will not flood the row. The cultivator should be immediately followed with a smoothing harrow, which is run parallel to the rows, for the purpose of making a soil mulch, and breaking down the clods, which are thrown up by the cultivator.

The Alfalfa Roots, or a large part of them, thus loosened and dragged out will be on top of the ground, where they will be dried out and killed.

The Second Cultivation must be delayed ten days or so until the plants are up so that the rows may be followed.

Guards.—In cultivating the second time, it is generally necessary to use guards on the cultivator to prevent the shovels from throwing down and covering the plants.

*Further Cultivation.**—If the work is properly done, these two cultivations will raise a ridge in the land so that ditching is comparatively an easy matter. In many parts of the State these two cultivtions are all that are given, though when the season permits, or when rains are frequent, or in the mountains, between early irrigations and before the vines are too big, it is desirable to cultivate once or twice more. Sometimes the only tool that can be used at last is a small cultivator between the rows. Cultivation of potatoes by the Greeley method is recognized as hard and *skilled labor.*

IRRIGATING.

The Rainfall in northern Colorado for May, June and early July, is usually sufficient to bring up plants and grow them until the tubers begin to form. This is rarely true in the mountains

Irrigation Once Begun must be continued as needed until the crop is developed. Most successful growers hold that in general

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*The object of cultivation, rather than any fixed rule, should be kept in mind. If the soil is loose, leave the field alone, do other work against a time when cultivation is needed. One of the best crops we have known of was raised with only one cultivation as there was no rain and the soil staid loose.

too much rather than too little water is used. The number of irrigations required cannot be foretold for any soil or season, and is a matter of experienced judgment based on observing the weather and the actual moisture conditions prevailing under the plant and about the roots, and will vary from two to seven times.* Irrigation must cease before the growth of the tubers ceases, or the potatoes will be coated with dirt, which would have been loosened by the surface motion of growth.

The Per Cent. of Slope affects the methods and amount of water used in irrigating. On the plains, in many places, there is not more than eight or ten feet fall to the mile, while narrow valleys usually have several times this amount. With plenty of slope,

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*Some measurements taken on the E. R. Bliss ranch show the amount of water actually used in growing a crop of potatoes, both on alfalfa land and on old potato land. The applications on the potato field, preceded by three years of alfalfa, were as follows: July 25th-26th the water ran 17 hours with a delivery of 4.05 feet per second. August 1 and 2, 27 hours with 1.96 feet per second. August 8 and 9, 24 hours at 2.31 feet per second, and August 15 and 16, 30 hours at 2.37 feet per second. This field contained 17.88 acres, and the depth of water used in irrigation was 13.76 inches. The rainfall by months from April till October was: April, 3.04 inches; May, 1.73; June, 1.10; July, 2.24; August, .64, and September, 2.31, or 11.05 inches. The September rain was mostly in the latter part of the month, and probably did little if any good to the potato crop. If the September rainfall is left out, the precipitation that should be counted as contributing to the growth of the crop will be 8.75 inches. The rainfall plus the irrigation gives us 22.51 inches as the total water used on the crop. The field is Billings clay loam with quite a large per cent. of sharp granitic gravel. The soil is about two and one-half feet deep, underlaid with gravel, so it has good drainage. The field was plowed in early May, eight inches deep, harrowed immediately and planted to Pearl and Snowflake potatoes June 1st. The yield of Pearls on this field was above 150 sacks per acre, which is near the maximum for the season.

The field adjacent to this one had grown potatoes the year before, and was watered just previous to the alfalfa potato field. The first run was 14 hours at a discharge of 4.05 feet per second and the second 18 hours at 1.96 feet per second, the third 16 hours at 2.31 feet per second and the fourth 24 hours at 2.37 feet per second. This field had an area of 19.74 acres, and an average depth of water was used over the field for the season of 9.35 inches. The difference in the irrigating water between the old potato land and the alfalfa land was 4.41 inches. This field was planted just previously to the alfalfa field and the potatoes ripened (or the vines died from fungus troubles) about two weeks earlier. The yield was about 130 sacks per acre, as against something over 150 sacks for the alfalfa land. Frequently a greater difference than this results between alfalfa land for potatoes and land preceded by other crops, but it seems that the difference comes not from the amount of plant food in the soil, but from disease: for, after potatoes have been grown on soil even three years, the cereals grown on it will produce heavy crops.

The difference in the amount of water can be attributed to the mulched condition of the old field and to the physical condition of the soil in the two fields. The decaying alfalfa stems and roots make the newly broken land more porous, and the first irrigation particularly takes more water to fill the soil.

deep ditches are not required; and in fact, where the land is steep, shallow ditches are desirable. Neither is such deep cultivation necessary although thorough cultivation gives the best results in all parts of the State. The length of time required to wet the soil by irrigating varies with the per cent of slope. That is, the greater the fall the greater length of time the water must be run.

Sub-Irrigation.—In the San Luis Valley, where the land is level enough and the subsoil will permit, a system known as sub-irrigation is practiced. For this purpose lateral ditches are run at uniform intervals of from 30 to 150 feet across the field. The water from these ditches in a short time fills the subsoil from the ditches to the center of the spaces, then gradually rises to the surface and moistens the soil. This system has an advantage in ease of operation but is open to the objection that usually more water is used than is good for the plants. The valley has a great deal of soil disease, in consequence, among her potatoes.

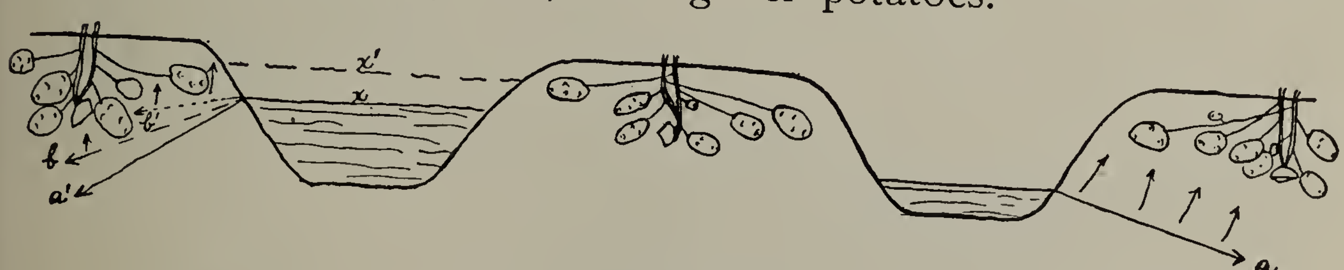

PLATE VIII. *Drawing by C. L. F.*

The Advantage of Sufficient Slope.—Where there is fall enough so the vines or uneven grades do not back up the water in the row at any time, we have the condition shown on the right. The hill space and the dirt about the tubers is not puddled and set, but is moistened like a wick from below as indicated at (a). Ideal slope for all crops including potatoes is about 1 per cent., or 50 feet to the mile.* On much steeper lands, great care is required to prevent heavy washing. However, with good subsoil, record crops of potatoes and grain are grown where the fall is at least 200 feet to the mile.

Flat Lands Not so Good.—Where the fall is slight, very short runs and much labor and skill are required, or conditions will obtain like those shown to the left. With the water level at x, the time must be brief if the soaked portion be confined to the line a′, and it is pretty apt to rise to b and b′, and the hill surface is sure to be puddled to the level x; while with the water level at x′, the whole side hill surface and much of the tuber bed is sure to be damaged.

Accurate Grading of Flat Lands is essential that the existing

*Such slope does not permit of the turning out of large heads at one spot, but requires the substitution of corrugation for flooding, and row irrigation for all fields, to the great benefit of every crop.

general fall may be evenly distributed, and all knolls and hollows are eliminated. A good farm level, a four horse Fresno scraper, with wheelers for long hauls, and infinite labor and perseverance are required for this job, but it pays big dividends in quantity and quality of crop, and in water and labor saved.

FROST.

High Altitude and the close proximity of snow clad mountains make us liable to sudden frosts, both late in the spring and early in the fall. The young potato plants are nipped even in June, early frosts are apt to catch tubers unprotected by a good layer of earth, and our mountain passes render us liable to sudden freezing in shipment.

Growing Potatoes are best protected by water, and air drainage. The bottoms of valleys and such spots as are protected by trees or otherwise from air movement are most liable to frost damage. Recently watered* fields, or fields on which water is running, are least liable to injury by frost. So when a frost is predicted it is wise, other things being equal, to use all the available water, and if the field cannot be all irrigated, to use the water in every third of fourth row.

Protective Ditching and prompt digging are the remedies for frost damage to tubers. The Pearl and other varieties which set shallow, and long or large potatoes or those on long stems which run close to the side of the hill are liable to be nipped by frost. So ditches need to be narrow and straight sided as possible, and the soil taken from the ditch should be spread over the top of the hills. For this purpose there is as yet nothing equal to the Kersey Ditcher† with "side shoves," although we think some of the nearly vertical sweeps may be equipped for this work.

Damage in Shipping is made less liable by putting a false bottom or thick layer of straw on the floor of the refrigerator car and by packing the sides with paper and straw. Salamanders (small stoves) are used to thoroughly warm the cars up to train time, and shippers from northern states are obliged to send men with the cars to tend stoves, but always with a large expense and some losses by fire. In Maine, there is a line of oil heated cars in use to Boston and New York that make shipment safe in any weather. For our use, steam heated cars with thermostats con-

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*We might expect the cells of well watered sappy plants to be easiest broken by freezing, but such is not the case with potatoes nor with alfalfa or the leaves of our cottonwoods.

†This ditcher was developed in a district where there is very little fall and is there popular because of its clean large straight sided ditches. It is cheaply made by the local blacksmith and in sizes needed for the slope or variety raised on the particular farm.

trolled by air pressure from the air brake system would be preferable.‡

Danger Dates.—Corn growers and even beet raisers have more time to complete their work in the fall than has the potato farmer, because they are more independent of frost.

The experience of years has established dates past which it is dangerous to leave potatoes in the ground subject to heavy frost losses. Waiting for potatoes to ripen is not wise; it is better to devise ways to ripen them earlier another season and save what is in hand this time.

At 7,000 to 8,000 feet altitude, October 1st is the danger line.

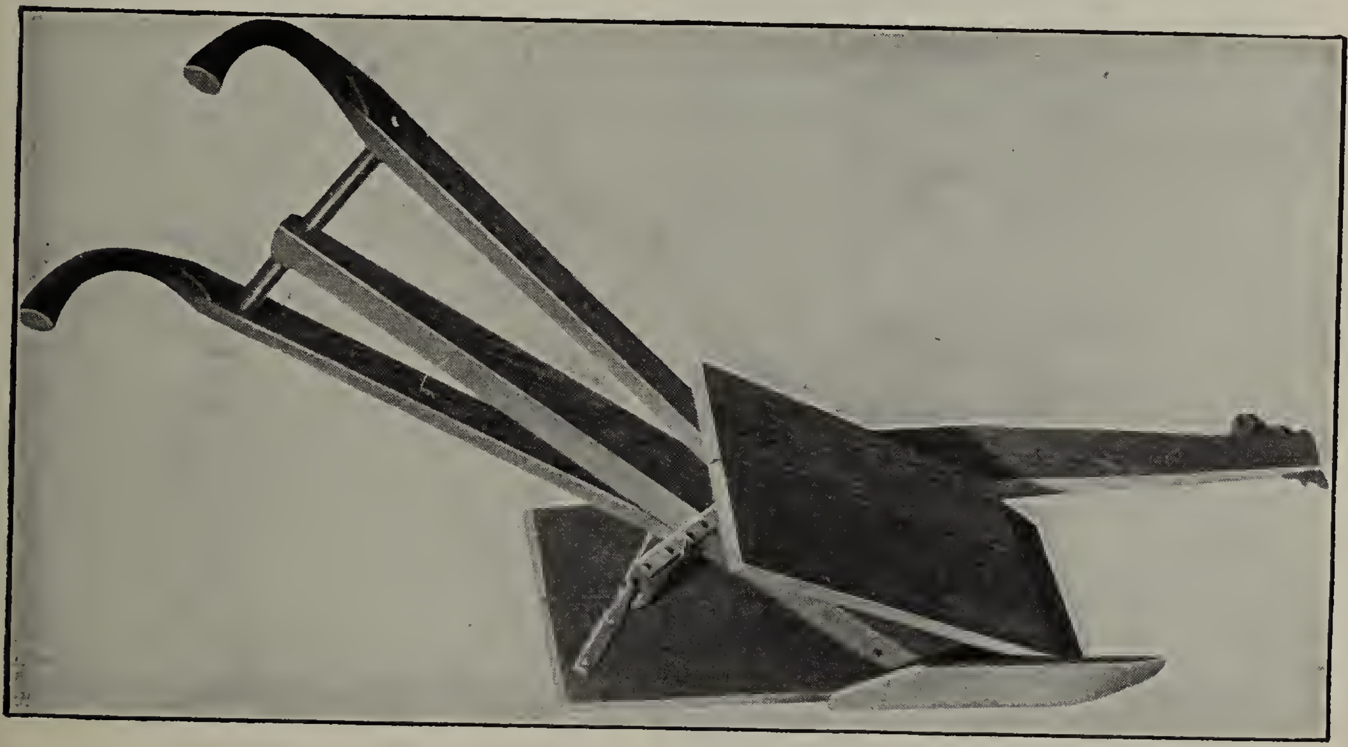

PLATE IX.—The Kersey Ditcher

At Greeley, the leases used to read Oct. 20th, but growers feel safer to be done several days sooner, as damage has occurred on the 16th. Lower still, about Julesburg, for instance, Oct. 20th is quite safe.

Old growers recognize these limits of safety. New ones will do well to adopt them.

CARING FOR FROSTED POTATOES.

When to Sort Them.—The third week after storing is the time

‡The cost of equipping cars in this way is not more than $100 each. Colorado people stopping at at least one hotel in Denver will find this system in use in all rooms, and very quick to respond to a five degree change in the dial. The Burlington Railway is experimenting with a system of this sort, and the Colorado Agricultural Experiment Station, funds permitting, will gladly co-operate with the growers, dealers, and railroads in working out a system to do away with frost losses in shipment. A system of this kind would be particularly useful between the San Luis Valley and Pueblo.

to care for potatoes that have been touched with frost in the ground. The first ten days after the storing, the frozen ones cannot be detected nor sorted out with speed. Frosted potatoes can be told at any time by thumbing the nose of every potato. After the third week they are likely to be semi-liquid rots and to smear the mass past remedy.

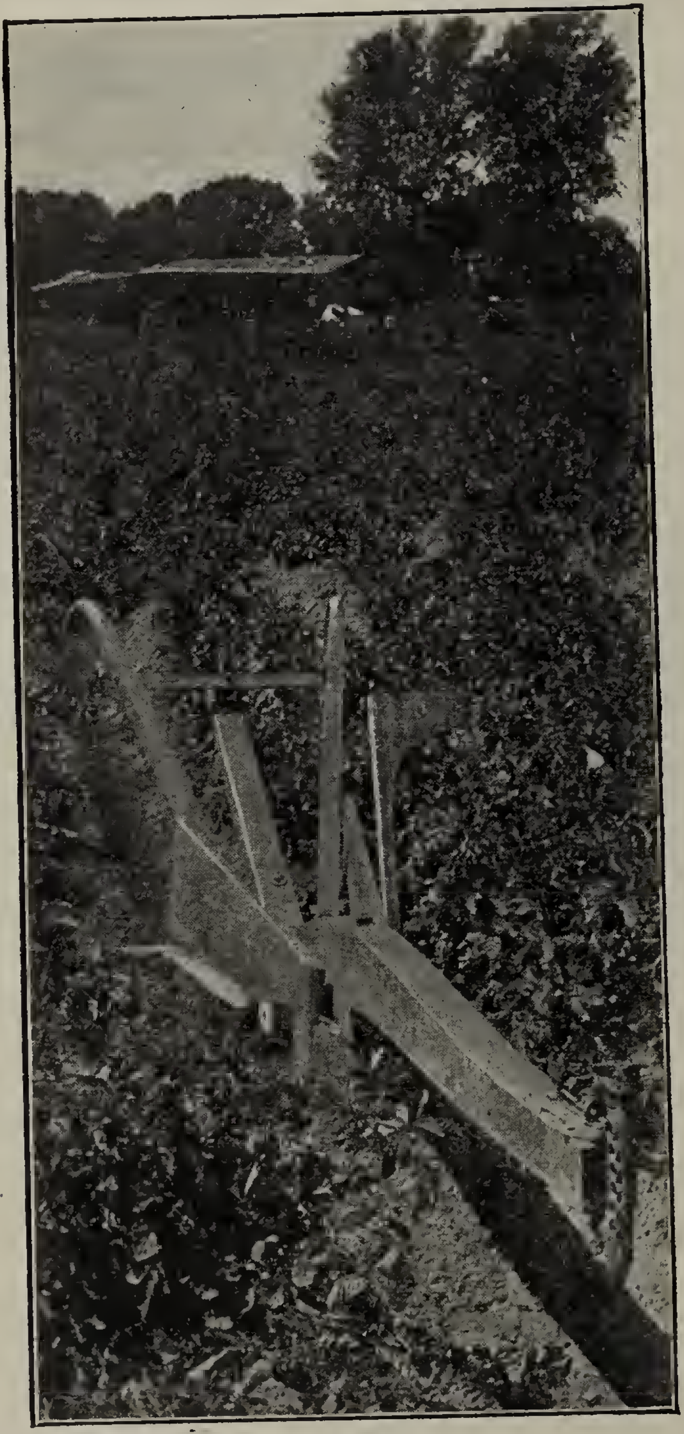

PLATE X.—Kersey Ditcher with "side shoves."

Good Light.—Good light is required and cannot be counted upon from open doors or windows at the right time because of the likelihood of storm and cold. Gasoline mantle, acetylene, or electric light is sometimes available. Some cellars in the Greeley district, including the new one at the college, have facilities for skylights in cold weather. Daylight is the best and none too good for the work of sorting out the rots. Frosted potatoes, like balky horses, are bad property. Never buy them. We all have enough of our own.

Sorting from Pits.—This practice always is dangerous, because some years there is no weather that allows the pits to be opened before the long steady cold spells. Most seasons this is a very good way to handle frosted potatoes for storing or selling in November or December. The man who stores frosted potatoes and *does not sort,* deserves scant sympathy.

POTATO DISEASES.

Diseases Differ from Those of the East.—Work done in the East on this subject is of comparatively little value to Colorado potato growers. Every station in the eastern potato growing states has put out from one to a dozen studies on this subject. Nearly

all of these diseases come under the common name of "potato blight," and are caused by various species of fungi that work on the outside of the foliage or stem of the potato above ground.*

Late Blight.—The disease most talked about and which probably causes more trouble to potato growers of the East than any other is that known as late blight, or *Phytophthora infestans.* This fungus came to the United States from northern Europe, its native home†, being the home of the potato in South America. The first we hear of this disease causing trouble to any great extent was at the time of the famine in Ireland during the forties of the last century. The ravages of this disease in destroying the potato crop of Ireland, resulted in the death of 300,000 people in one year from starvation, and brought to a crisis the political agitation and the emigration from Ireland that is only now being abated. This fungus did its first damage in the United States in 1843 and has gradually spread from the eastern states, west, as far as the humidity of the climate would permit its growth.‡

Late Blight Described.—Where this disease is prevalent, it may be seen in early fall, on the lower side of the leaves as a fine mould. When the seasons are comparatively dry with little humidity, the plants seem to withstand the disease, so it will not be noticeable, except that the plants appear to mature earlier than where the disease is prevented by spraying. We found at the Connecticut Experiment Station, that while unsprayed plots showed no particular signs of disease, the foliage appeared to ripen off so that the plants were dead two or three weeks before frost, while sprayed plants were still in good condition until frost struck them.

Damage of Late Blight.—Not only does the fungus kill the vines or injure them so as to reduce the yield, but in seasons when the weather conditions favor the development of the fungus, the tubers decay in the ground, or if infected tubers are taken to the cellar many of them will decay later. This loss by decay is sometimes as great as fifty per cent. of the crop of a whole district. It is not uncommon for this disease to destroy the plants over a large part of a state within three or four days from the time the effect of the fungus is first seen on the plants.

*For this reason the old, almost universal remedy has been the fungicide **Bordeaux mixture.** It is not uncommon to find Colorado potato growers planning to spray their potatoes for diseases which have never been known in this State.

†**The Potato,** Samuel Fraser.

‡It is not probable that the disease will visit Colorado, for as the fungus lives over winter in the tubers it certainly must have been brought to the State and planted many times in the last ten or fifteen years. Therefore, we may conclude that as the disease has not been found in the State our climate is not favorable to its development.

Early Blight.—Another leaf fungus is that known as early blight, (*Alternaria Solani*), often found in our mountains and less often at Greeley. This disease may be distinguished by black areas with concentric rings on the foliage of the plants in early July or August. It seldom causes rot of the tubers, and is injurious, simply because of its injury to the leaves of the plant. It is impossible to know what per cent. of injury is caused by this fungus as compared with other troubles. In the east, where plants are sprayed with a fungicide, they always give larger yields than where not sprayed, as the result of controlling early blight and the prevention of the ravages of insects and of fungi other than *Alternaria.*

Early Blight Damage in Colorado ordinarily amounts to but little. During the summer of 1909, in early August a storm occurred over Colorado that brought the conditions of humidity that are common to the east; that is, there were some days of almost continuous cloudiness with occasional rain. Early blight developed as a result in nearly every part of the State. In some fields it was so prevalent as to nearly defoliate the plants. If it were possible to know when these conditions were to occur it would be profitable to spray Colorado potato fields.

The Colored Plate illustrates young potato stems affected with the fungus diseases, *Rhizoctonia* (No. I), and *Fusarium* (No. II). Note the plant stems on the left are girdled with *Rhizoctonia.* The stem on the right is affected with *Fusarium* which started by rotting the cut surface of the seed tuber, then followed the vascular system of the plant up the inside of the stems, and killed the smaller sprouts before they got out of the ground.

Rhizoctonia.—Until the last two or three years it was thought that nearly all the fungus troubles of Colorado potatoes were due to *Rhizoctonia.** This disease affects the plant by girdling the stem or root stalk, so as to prevent the food from going from the tops to the roots and tubers, or by cutting off the tuber stems. See the Colored Plate.

Fusarium or Dry Rot.—We have found many fields of potatoes seriously diseased, though the bark of the stem from the old seed to the surface of the ground was clean and free from disease. The leaves, however, were turning yellow, and stopping growth. In some districts this was so serious that many plants died before reaching the surface of the ground. Others grew a few inches above ground and succumbed to the disease. The trouble started principally from the cut surface of the seed piece and followed through the tissues of the old tuber, into the stem of the plant.

*Since publishing Bulletin No. 117, on the Colorado Potato Industry, we have found that a great deal of fungous trouble is not due to this disease.

When the plant stem was split lengthwise, it was found that the sap wood or vascular tissue of the plant was discolored from the base of the stem to some distance above the ground line. The plant was often blackened from the vascular tissue out and in some cases it was rotted off at the base. Investigation was made of this disease and it was found that it was caused by a fungus known as *Fusarium*. In the cross section of the potato stem showing the

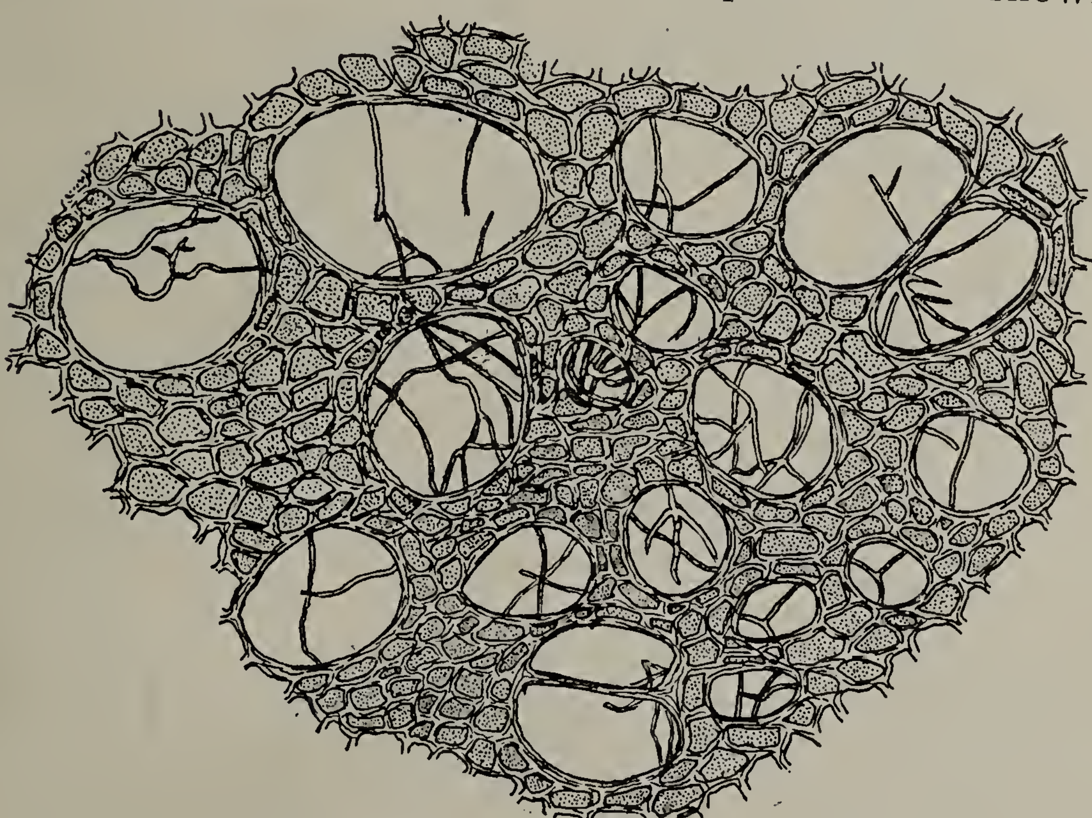

PLATE XII.—Fusarium Hyphae in the Ducts

vascular structure of the stem, the hyphae of this fungus are shown growing across the cell spaces. Apparently this fungus acts on the circulation of the plant, much as roots of cottonwood, willow or alfalfa do in a tile drain.†

†It is probable, also that the fungus does other damage to the plant as well as stopping the circulation. A careful examination of fields in all parts of the State show that this disease is almost always present, more or less. If growers will go through fields in August they will occasionally find plants that appear to be maturing early. They are turning yellow and showing signs of dying. If these stems are pulled up and split, you will nearly always find the yellow discolored area running up the stem just outside the pith tissue. This disease is most noticeable when the plants are young, and in fields where potatoes follow potatoes. In fact it is quite probable that the difference between yields where potatoes follow potatoes, and alfalfa ground in the Greeley district is largely due to the ravages of this fungus. No remedy is known for this disease. Two preventative measures may be adopted: First, that of rotating the crops so that potatoes will not follow potatoes; and the second, cleaning the seed by exposing to the light and air, so that the spores of this fungus will be largely killed, and the tubers made resistant. The planting of a whole seed is always desirable where this disease is liable to occur. The development of the disease is favored by wet soils and high temperatures. Where soils are porous and not too wet, little trouble has been experienced from this disease.

Dry Rot in Potato Tubers is also chiefly caused by the fungus, *Fusarium,* and is most common on bruised or cut tubers and where the potatoes are stored in unventilated or warm cellars, or where dealers and town people keep potatoes in warm places. As stated, the use of such seed is very apt to infect the new plant, to the serious damage of the stand and yield. This matter of dry rot is exceedingly important especially to the growers of Rural and Ohio potatoes and to the consumer. The dealer's warehouse and the out-of-the-way, little-visited farm cellar, set in the field or in some side hill, are great sources of infected seed, poor crops, and unsatisfactory table potatoes.

Internal Brown Spot is a disease affecting, in our region, the tubers of the Early Ohio potato almost exclusively, and though it occurs from California, Idaho and Montana to Texas, we have not known of a case of this trouble under the ditch. It* is thought not to be of bacterial or fungous origin but to be a physiological matter, the death of some of the cells. The cause is supposed to be drouth, and the remedy is the raising of other varieties than the Ohio, and better dry farm methods† that shall supply water enough for the plant.

Internal Brown Spot does not destroy the tuber nor hurt its outside appearance nor preclude‡ its use as seed; but the spots do prevent its sale and as found by the potato specialist in Nebraska and Colorado, seriously damage the odor, flavor and appearance. In close competition, we have found the odor and flavor in samples where the spots could not be seen.

Potato Scab.—This disease occasionally makes its appearance in every Colorado potato field. In the east nearly all writers have thought that scab was caused from a fungus, *Oospora scabies.* German pathologists have proved that several other fungi may cause scab, and in Colorado Professors Rolfs and Paddock found that much potato scab was caused by the *Rhizoctonia* stage of *Corticum vagum.* More recently we have demonstrated that this is true.

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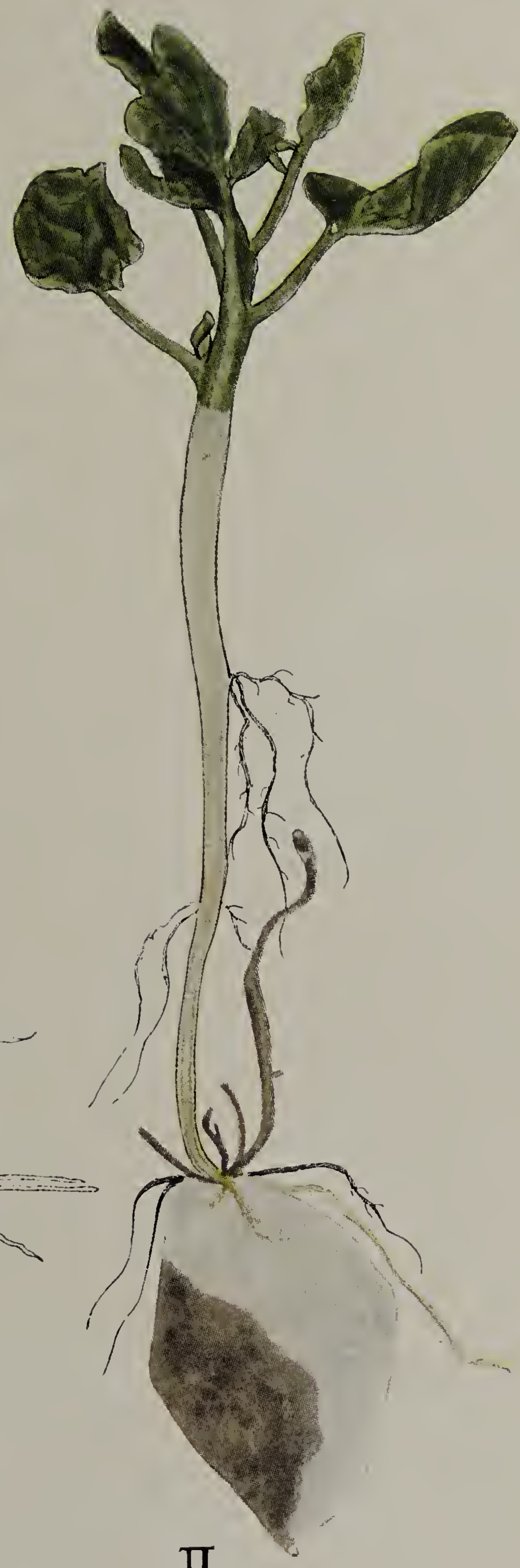
*Nebraska is a leading producer of Ohio potatoes and without irrigation, and the disease has been very serious in that State. Dr. E. M. Wilcox of the Nebraska Station and his assistants have spent an immense amount of time on this disease, without isolating any organism as the cause.

†Summer tillage the previous season and summer or fall plowing, with thorough shallow tillage up to and after planting.

‡Sutton & Sons, the well known British seedsmen, performed in 1906 an experiment as to whether tubers affected with this spot were good seed. They found with two varieties that the healthy seed produced a larger crop by one-fourth to one-half but that there was not more brown spot from the affected than from the unaffected seed. In fact there was far less from the affected seed, doubtless because it grew less rank and used less water and suffered less from drought, which in Great Britain, as with us, is thought to be the cause.

I



II

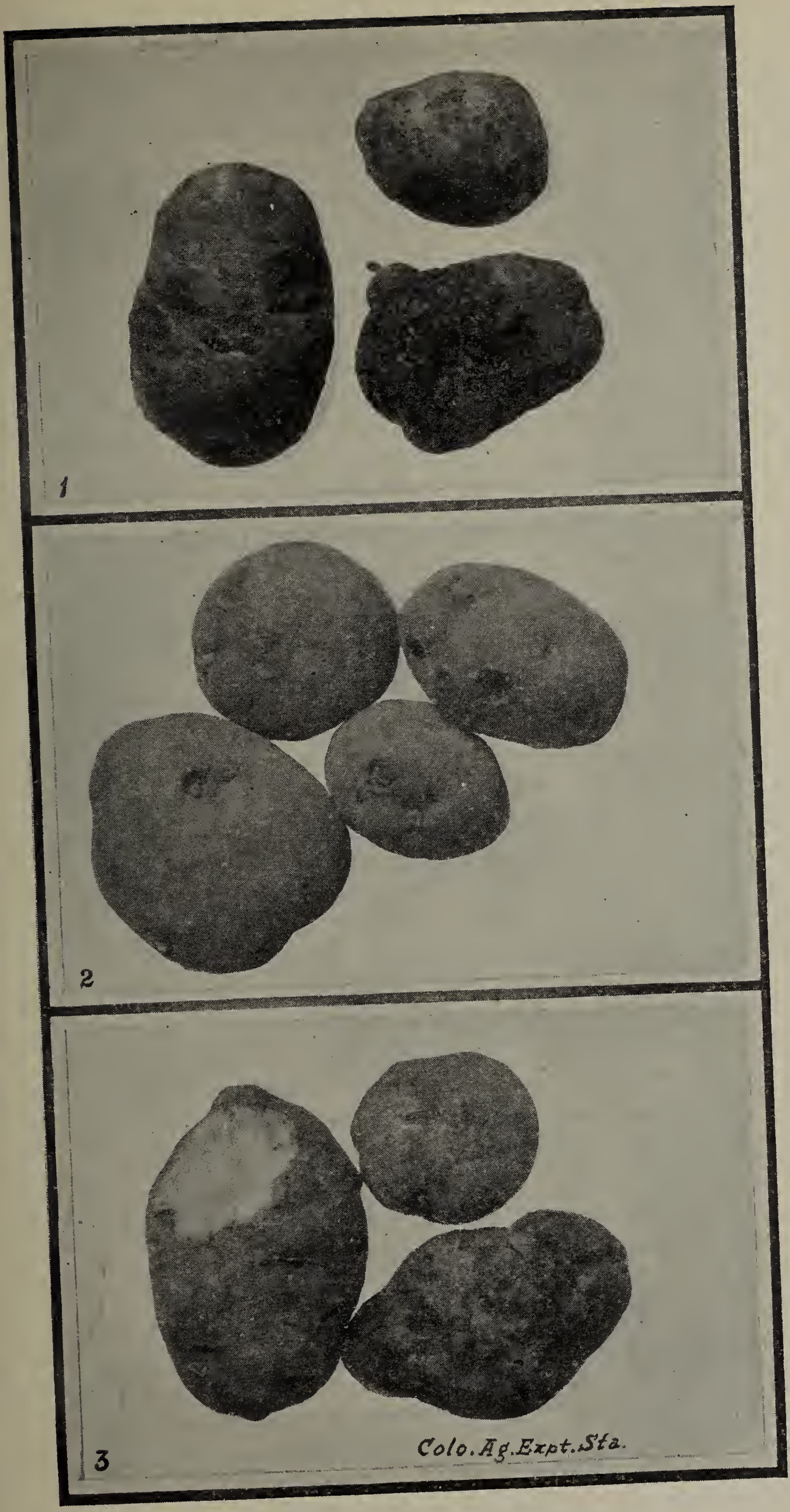


PLATE XIII.—Scab of Potatoes
1. Surface Scab. 2. Deep Scab. 3. Apparent Scab—work of the Beetle.

Tubers treated with formalin solution so as to preclude any chance of planting the fungus with the tubers, have been grown in pots of soil that were sterilized with steam, and the plants watered with boiled water. When the tubers formed in these pots part of them were inoculated with the fungus Rhizoctonia and typical scab was produced, while the checks were perfectly free from scab. As we know that scab may be produced from a fungus, Rhizoctonia, present in all our soils, we cannot hope to eradicate scab by any treatment of the seed. Rotation of crops with good drainage and cultural methods are the only preventive measure that can be recommended. See under *Seed and Its Treatment*, a report of field trials.

POTATO INSECTS

By S. ARTHUR JOHNSON

THE COLORADO POTATO BEETLE, (*Leptinotarsa decemlineata.*)

Native Home and Food.—This insect is a native of a strip of country which lies just east of the Rocky mountain range and includes eastern Colorado. In its native state the beetle lives upon the wild weeds of the potato family. The chief of these is the buffalo bur, but the beetle is quite a general feeder on plants of this group including not only potatoes, but tomatoes, egg plant, tobacco and pepper.

The Insect.—The adult beetle is oval in shape, about three-eights of an inch in length and a trifle narrower than long. The ground color is yellow and the wings are marked by ten black lines running lengthwise. There are also black markings on the thorax. The eggs are bright yellow when fresh and are generally laid on the under surface of the leaves in patches containing from ten to fifty each. The young are dark red or brown grubs with black heads. The color becomes lighter as the grubs mature.

Life History.—The adult beetles live over winter usually in the ground at a depth of from four to six inches. Where the ground is loose they frequently go much deeper. When the ground becomes warmed by the spring sun, the beetles emerge and seek food plants on which they may feed and lay eggs. They are more or less abundant every year and do considerable damage to early potatoes. The late crops in Colorado generally escape because most of the adult beetles die off before the potatoes appear above ground.

The eggs hatch in from four to eight days depending on the temperature. The larvae feed at first on the surface of the leaf where they hatched, but soon migrate to the top of the plant and eat the tender young leaves which are just unfolding. The young

reach full growth about three weeks later. Soon eggs are laid again and the second generation hatches. Ordinarily two broods are all that we may expect.

Remedies.—The best and most practical remedy is spraying with some arsenical poison. In commercial fields the best machine is a power sprayer drawn by horses. In garden patches a hand sprayer does very good work. *Arsenate of lead,* altogether the best poison, is a white paste which must be carefully mixed in a little water before it is poured into the spray machine. It should be strained through a fine screen in order to remove all lumps which might clog the nozzles. Apply the poison at the rate of six or eight pounds to a hundred gallons of water. The proper time to spray is when the young grubs begin to appear at the tops of the stems. Arsenate of lead does not kill as quickly as Paris green, but it sticks to the leaves much longer and the benefits can be seen for weeks even after rains. *Paris green* is the old standby, is cheaper for a single application, and is still the most used. This poison is mixed with water at the rate of a pound to seventy-five or one hundred gallons. There is danger that this substance will burn the foliage of the potato, and to avoid this, it is well to add the milk from two pounds of slaked lime to each hundred gallons of water used. While spraying either of these poisons the contents of the spray machine should be kept well agitated. Sometimes the pest is confined to small areas. In such cases the insects are often controlled by the use of dust sprayers, which either blow the Paris green out in fine clouds, or dust out the same poison when it has been mixed with flour or carefully screened air slaked lime.*

THE POTATO FLEA BEETLE, (*Epitrix cucumeris.*)

The Insect.—When tomatoes are first set out or potatoes first come up there may often be found on them tiny black beetles which jump when alarmed. They are called the flea beetles because of this habit, though they are not closely related to the flea.

Injuries.—The adult insects live over winter and appear during the latter part of May and first of June. They get their living by eating tiny holes in the surface of the leaves of plants of the potato family, and often attack cucumbers and beans. The insects very often congregate in such numbers that the leaves of the plants appear almost black with them. Newly set tomato plants and young potatotes frequently have their leaves so badly eaten that they

*The suddenness of scourges of potato beetles should be remembered. At Greeley, they had not been very serious for many years, but in 1909 $50,000 was spent in fighting them. In 1910, everybody was ready with poisons and sprayers, and almost no beetles appeared. These beetles are liable to be serious in districts where growers have not noticed any harm from them. The first beetle seen should be a warning to be ready the next year.—C. L. F.

shrivel, and the tomatoes may die. Ordinarily the stand of the potato crop is not seriously injured in this way. Their greatest damage to potatoes in Colorado is done by the larvae which live underground. These larvae are tiny white grubs which attain a length of about a quarter of an inch. The first brood is to be found during June or early July. They frequently cut into and destroy the young tuber stems of the potatoes, thus preventing a regular setting of the crop. The second brood of larvae appear during August and September. This brood bores into the flesh and under the skin of the potatoes, causing a pimply or scabby development, which may cause great waste in preparing the tubers for the table and seriously depreciate their market value.

Remedies.—No satisfactory remedy for this pest is known. The leaf injuries to young potatoes and tomatoes may be largely avoided by spraying the leaves thoroughly with Bordeaux mixture to which Paris green is often added. The insects appear to avoid the parts of the plants covered with these disagreeable substances and to seek fresh tissues upon which to feed. It is not certain where the insects hibernate, but they are often found in the fall in large numbers feeding on stray potato plants or pieces of tubers which have been left in the fields. It is well to clear up the fields immediately after the crop is gathered. These insects are seldom, if ever, found on new ground and are much worse where potatoes are planted in succession.

GRASSHOPPERS.

The Insects.—There are many kinds of grasshoppers, but the species that become injurious have life histories which are very much alike. The eggs are laid in the fall in packets in the ground, containing from thirty to a hundred eggs. Their position is about an inch below the surface of the soil. The insects appear to select places which are comparatively dry in which to deposit the eggs, and we have found most of them this year in patches of weeds and grass under fences, and along ditch banks and roadsides. The young hatch rather late in the spring and do not become full grown until mid-summer or later.

Injuries.—Grasshoppers frequently injure potato fields by invading them from the borders, but this is not one of their favorite food plants. The most serious relation of grasshoppers to the potatoes is indirect rather than immediate. Potato growers depend on alfalfa to renew and enrich the soil. The presence of grasshoppers in the fields newly sown to alfalfa is disastrous, for they quickly destroy the little plants and it is impossible to obtain a stand. This prevents a proper rotation of crops.

Remedies.—The best remedy to employ during the fall and spring is the destruction of the eggs. The first step in this work

is to locate the eggs. Inspection should be made everywhere in the surface of the soil for the pods of eggs. When the infested areas have been located, they should be plowed deeply to bury the eggs, or disced or harrowed very thoroughly to break up the pods so that they will be exposed to the ravages of birds and other animals or dried out before they have time to develop. The earlier in the fall that this remedy can be applied the more satisfactory will be the results. It is better not to trust to one treatment, but to work over these places several times at short intervals. When young, or even when full grown, grasshoppers may be caught successfully in a hopper pan. If this is set on wheels a few inches above the surface of the ground and driven over the alfalfa when that is a few inches high, great numbers may be caught. The best time to do this is in the early morning when the hoppers are on the tops of the stems and somewhat numbed with the cold. A third remedy is that of arsenic-bran mash. This substance is made by mixing white arsenic with bran at the rate of one pound of arsenic to twenty of bran. After the substances are thoroughly mixed, add sufficient water to make a sticky, but not too sloppy material. Some add a little anise or syrup. The mixture should be scattered late in the afternoon or early in the morning so that the hoppers will get it before the hot sun has dried it up.

In the Greeley experiments of 1910 the potatoes were sprayed with Bordeaux mixture to test the value of this substance as a repellant to grasshoppers. The results appeared to be favorable as to keeping off grasshoppers, but indecisive as to the prevention of flea beetle injuries to potato tubers. See *Greeley Notes*.

TO SELL OR TO STORE POTATOES?

A SYSTEM

Selling from the Field.—To sell always from the field is as well as *always* to store. The wise grower will sell out of the field when the year's production is greater than the average yearly consumption of three and one-half bushels per capita; and in such a year he will keep selling whenever any one will buy; no matter what the market, because in such a season the price will show no general rise. It is folly to hold for a price for which the grower thinks he can afford to sell.

When to Hold.—The wise grower will hold, particularly following a low price season, whenever the yield of the country is short of the average need, especially if quality be good and consumption likely to be large.

Crop Estimates.—*The Crop Reporter,* published by the U. S. Department of Agriculture, which is our best basis for judgment, is

sent free to all who ask it, and arrives about the 20th of each month with estimates made on the 1st. Sometimes in error on single states, the "Reporter" is said to have been wrong in its general conclusions for the country only once in fifteen years.

Importation.—Potatoes pay a protective tariff of twenty-five cents per bushel. In 1909, 8,000,000 bushels were imported into the U. S., and when domestic prices reach a high level, the crop in Europe must be considered. Otherwise Colorado growers should consider the general crop of the country paying no attention whatever to the crop prospects in our own state, and but little to the crop in our group of states. Until the Panama canal is finished, Colorado growers must look out for an excess on the Pacific coast, as it must compete direct with us now for outlet.

Good Marketing and the Community.—Public welfare is served by *steady* movement of produce to the consumer. Dealers, transportation companies, consumers and producers, *as a body*, are benefited by regular shipment. Good facilities for shipment over our mountains, and accurate crop information, that the price may at all seasons reflect the supply and demand, are therefore matters of public concern.

STORAGE IN ITS RELATION TO MARKETING.

No Fixed Rule can be laid down for the selling of potatoes. Constant study is essential to success. The prices and the best markets vary from year to year, according to the relation of supply and demand in different places. While the demand for potatoes is a constant one in every city, town and hamlet in the United States, the supply varies, and some regions are supplied locally one year and the next year have to ship in potatoes; while the cities and the south are supplied with potatoes that are grown many miles distant during at least a part of every year.

The Northern States produce most of the potatoes and have on hand at digging time ordinarily a sufficient quantity to supply, not only the local demand, but the large markets of the country until the early potatoes from the south take their place in the spring.

Commercial Methods.—If the growers were to place the whole product on the market at digging time it would necessitate the storing of from fifty to seventy-five per cent of the crop each year in the local warehouses in the growing districts. As direct shipment to consuming centers is essential to economy, storage at jobbing points is out of the question, while storage at southern consuming points is too warm or too expensive.

Storing a Large Part of the crop in the districts where the potatoes are grown and shipping as demanded for consumption is better from every economic standpoint; and the temperature in potato growing states favors the plan of storage on the home farm

or local warehouse. In those districts where the winter climate is particularly severe, and where it is difficult because of cold weather or bad roads to take the potatoes from store house to market there is more of a tendency to sell potatoes direct from the field regardless of price at digging time, and in districts where the rainfall is excessive there is also the objection that storage houses are not so easily kept dry as in the arid regions of the West

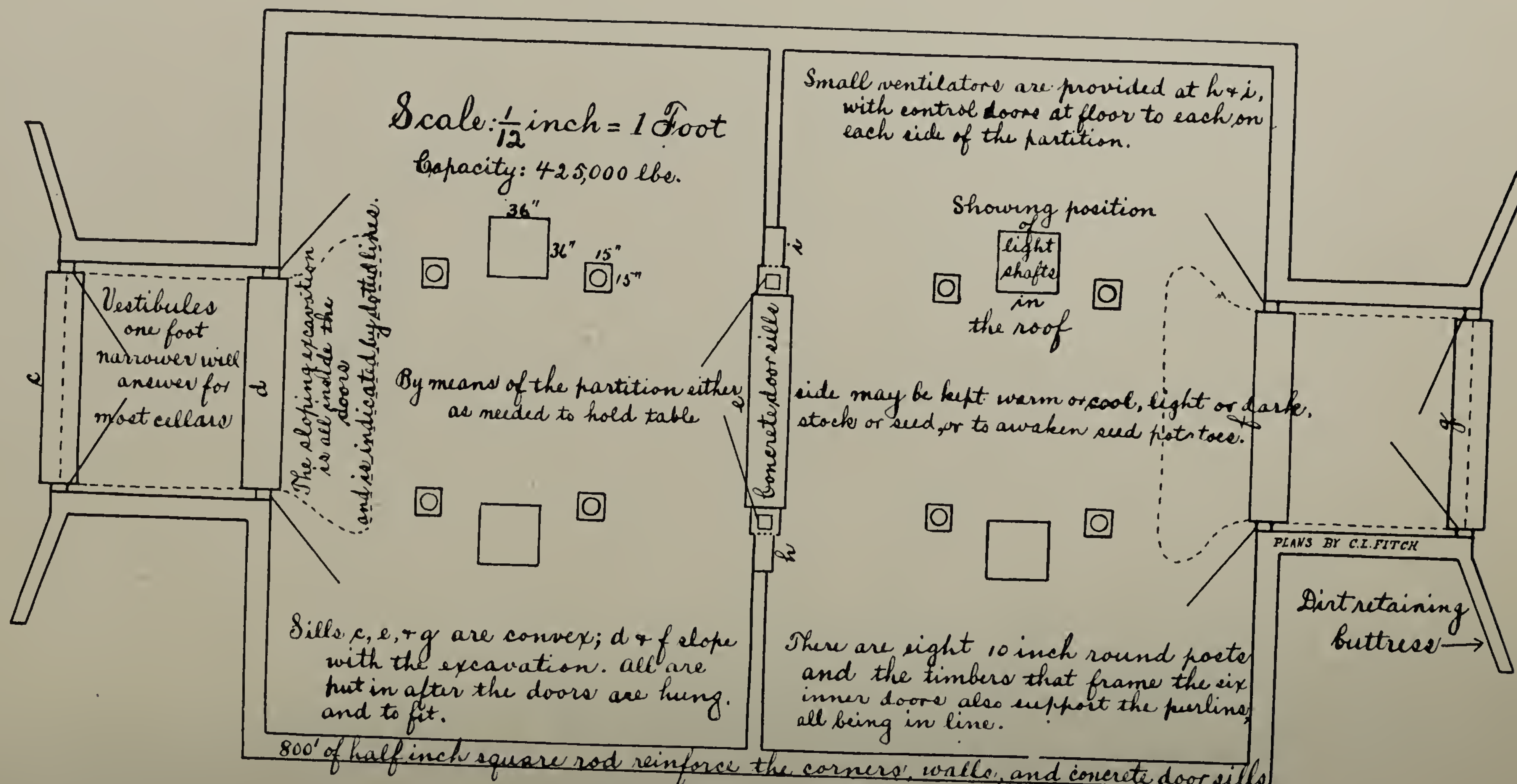
In Colorado there is seldom a time when potatoes cannot be taken from the farm to the market. As a result our potato growers have taken advantage of the favorable conditions for storing and a characteristic and unique system of storing has been developed. Our growers thus avoid glutting the markets during the digging period in the fall, and take advantage of any brief bulge in the price during the winter. The history of this system shows that it is not an invention but a gradual growth from the idea of storing in pits to the perfected ventilated potato cellars that are found in Colorado today. This system we consider one of the great features of the Colorado industry and is well worth the careful study of all potato producers who do not already understand its principles.

POTATO CELLAR CONSTRUCTION AND MANAGEMENT.

Cost of Construction per Hundred Weight of Potatoes.—This, in the best grade cellars, is about 20 cents. With a permanent roof over the dirt roof, the cost will be at least 5 cents more, and if a grower wishes to provide for seed potato storage, and have a handsome cellar for sales purposes, he may spend as much as 30 cents per hundred weight of potatoes to be stored. On the other hand, with cheap construction, without much regard to permanence, and with the use of farm labor, as little as 7 cents per hundred weight on a large cellar may provide good safe storage. Interest and sinking fund on this basis make the cost of cellar as a minimum one cent per hundred of capacity per year.

Size of Cellars.—Each square foot of floor space within a cellar will carry 200 pounds of potatoes, piled five feet deep, or 240 pounds per square foot six feet deep. Thus a cellar 50x100 feet will hold one million or one million two hundred thousand pounds of potatoes, with the driveway filled. It is wise to have a cellar large enough to care for the crop if piled four feet deep.

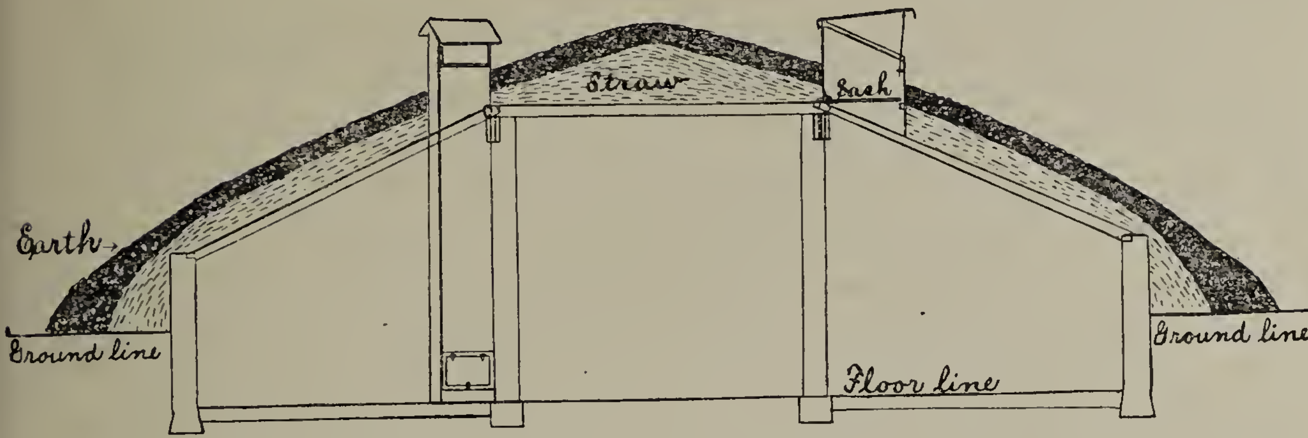
Driveways and End Doors.—A large cellar should have a driveway clear through it, with doors at each end. This saves backing into the cellar, or makes the potatoes at each end accesible, when the cellar is full. It also makes quick and complete ventilation easy. At the same time driveways take space, and the extra bulkhead and double doors are expensive, and let in cold, so that small cellars are often built with only one doorway. Such cellars should be arranged, however, so the center at the rear can be emptied early



Scale: 1/12 inch = 1 Foot
Capacity: 425,000 lbs.
36"
36"
15"
15"
Vestibules one foot narrower will answer for most cellars
c
d
The sloping excavation is all inside the doors and is indicated by dotted lines.
By means of the partition either side may be kept warm or cool, light or dark, as needed to hold table stock or seed, or to awaken seed pots toes.
e
Concrete door sills
i
h
f
g
Small ventilators are provided at h & i, with control doors at floor to each, on each side of the partition.
Showing position of light shafts in the roof
Sills c, e, & g are convex; d & f slope with the excavation. All are put in after the doors are hung, and to fit.
There are eight 10 inch round posts and the timbers that frame the six inner doors also support the purlins, all being in line.
800' of half inch square rod reinforce the corners, walls, and concrete door sills.
PLANS BY C.L. FITCH
Dirt retaining buttress

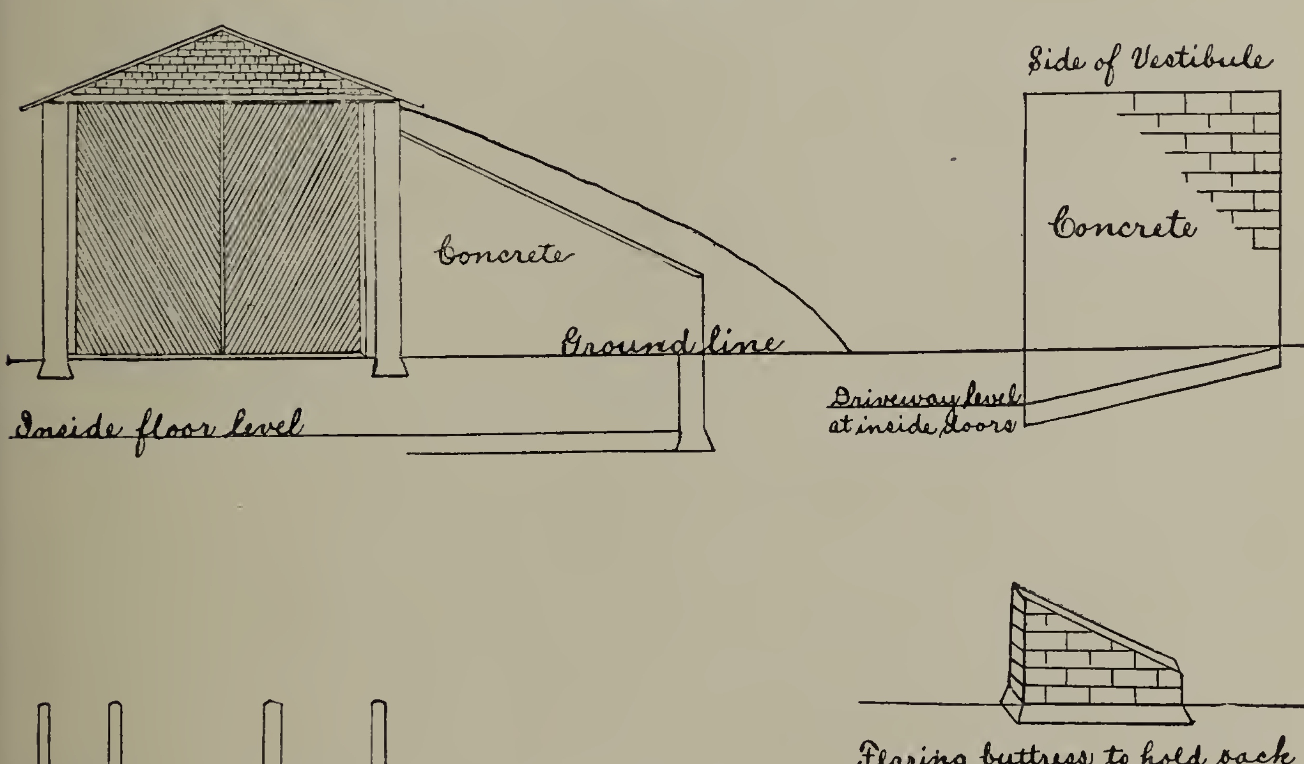
PLATE XIV.

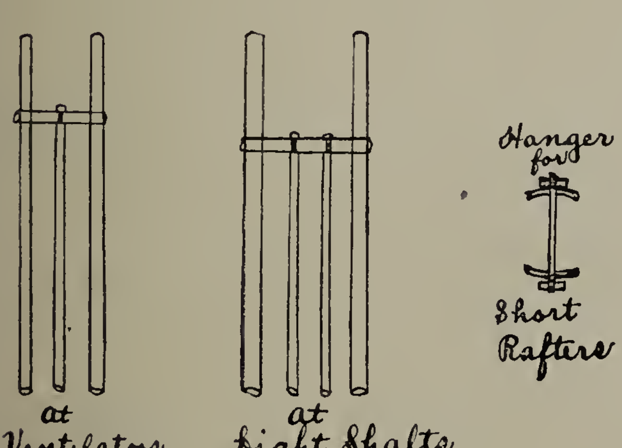
Scale: $\frac{1}{12}$ inch = 1 Foot



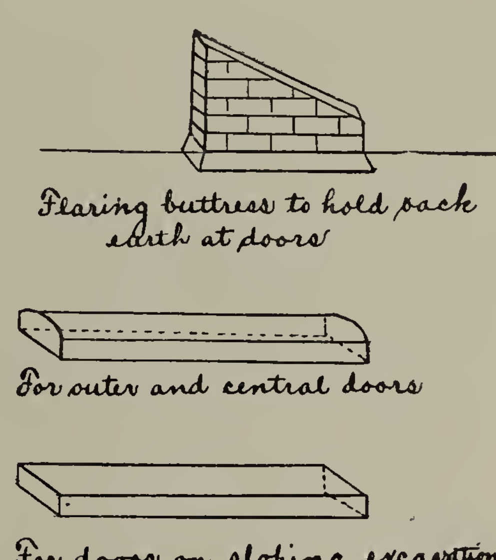
A FARM POTATO CELLAR WITH PARTITION AND
ARRANGED FOR LIGHT, DARK, COOL OR WARM STORAGE
PLANS BY C. L. FITCH.

DETAILS OF CONSTRUCTION





Framing Details



Reinforced Concrete Door Sills

PLATE XV.

in the spring, because it is at this point that most heating and sprouting occurs.

Side Chutes vs. Inside Unloading.—Wide cellars require driveways; narrow ones do not, unless for ventilation. Inside unloading means a vast deal of lugging and stowing away, which in practice involves tramping upon potatoes and rough handling of sacks. By arranging an inclined driveway about over the side walls, chutes may be used, that, with a considerable saving of labor, will permit cellars up to 40 feet wide to be filled quickly from above. Such chutes should be square, about 15 in. x 15 in., set at an incline, and fitted with a slip-over cover of wood, iron bound, but unhinged. If sacked potatoes are to be stored for a time, chutes 22 inches square are required, smooth inside, with a smooth inclined trough below and a table to receive the sacks and of height convenient for the man who piles them up.

Unloading through Chutes.—The wagons should drive within two feet of the chute. A tapering trough, with slatted bottom made of large quarter-round running lengthwise is leaned against the wagon, and is made to fit against the top of the chute. Two men on the wagon handling half sacks of potatoes from the field can keep a continuous stream of potatoes going down into the cellar.

Removing Dirt from Potatoes is important both for appearance and because dirt stops the inter tuber spaces, prevents ventilation and so causes heating, sprouting and rot. Sorters used in the field are the quickest way to sack potatoes, separate the small ones and remove the bulk of the dirt. The slatted trough removes a further per cent., but there will still be some left. When potatoes are dumped inside from sacks, the dirt is well distributed.

Use of a Canvas.—When chutes are used, ten to twenty-five feet of irrigation canvas can be used to let potatoes down without bruising them. The outer end brought up through the chute is turned over and fastened with laths and shingle nails, while a man holds the other end to ease down and distribute the stream of potatoes.

The Leveling of the Top of the potatoes over the whole cellar can be done largely by the canvas. This leveling is best because the projecting parts of uneven piles condense so much moisture upon them, and the top potatoes become so much discolored in the best of cellars, that a perfectly level top is desirable, to have the least possible exposed surface, consistent with proper depth.

Ventilation of the Pile of potatoes is sometimes promoted by using a heavy false bottom of 2x4's with half-inch cracks between the pieces. Others take two 8-inch boards and nail cleats across them close together thus making air shafts for use in the parts of the potato pile deepest or farthest from the side walls.

Dirt Floors Rot Sacks that rest on them if left for more than a week or two, no matter how dry the floor. Therefore floors other than dirt are required for storage in sacks.

Excavations for Cellars should be made deep enough so that sufficient dirt is secured for use about the bulkheads, sides, and roof. Three feet will usually supply this dirt, and this depth makes the slope of the driveway about all that can be covered by the vestibules. Where water comes too close to the surface, cellars must be built upon the surface and dirt found elsewhere to cover them, or sods and adobe brick are used. The cost of excavating the station cellar with the use of day help and teams was 13-8/10 cents per cubic yard, including the piling of the dirt about the hole where it would be handy for covering the roof. A farm level should be used to level the floor of the excavation.

A Knoll is the Best Place for a potato cellar, where available, as the cellar can be placed well into the earth, and still have the slope away from the doors, for surface drainage. Situations should be avoided where water may collect and run into a cellar; and a porous soil without floor is desirable to quickly let away any chance water in the cellar. The worst possible place for a cellar is secured when it is set into a side hill, and especially if set in endwise. If a knoll is not available, the level ground without shelter is the best place.

Side Walls of Cellars are usually required. Some soils stand up firm enough to use for walls without reinforcement, and will carry the plate and rafter ends. Caveins of side walls are disastrous, however, to cellar, crop and life, and it is seldom wise to trust to the earth alone. The cheapest practical construction requires good posts set deeply next the side and carrying the plate on the tops. Planks on the outside of these posts next the dirt are an improvement usually essential, or poles may be laid in. Reinforced concrete is the most permanent side wall, and appeals to those who can afford the best.

*Light is Important,** and ventilators should serve also the purpose of windows. Darkness is demanded for table stock, because greening by light develops the acrid taste characteristic of exposed potato tissue. On the other hand, light combats disease in seed potatoes, toughens the skins, and is a check to excessive sprouting. Cellars should have light in the spring without warmth.

Vestibules should be long enough to leave no sloping driveway outside. Some of the slope can be run within the cellar if required. A good roof and double doors well fitted are needed. A bar will keep out stock when the doors are open, or half doors can be used for this purpose. With good door sills, it is best to fasten the doors

*See elsewhere in this bulletin the discussion of **Greening of Seed.**

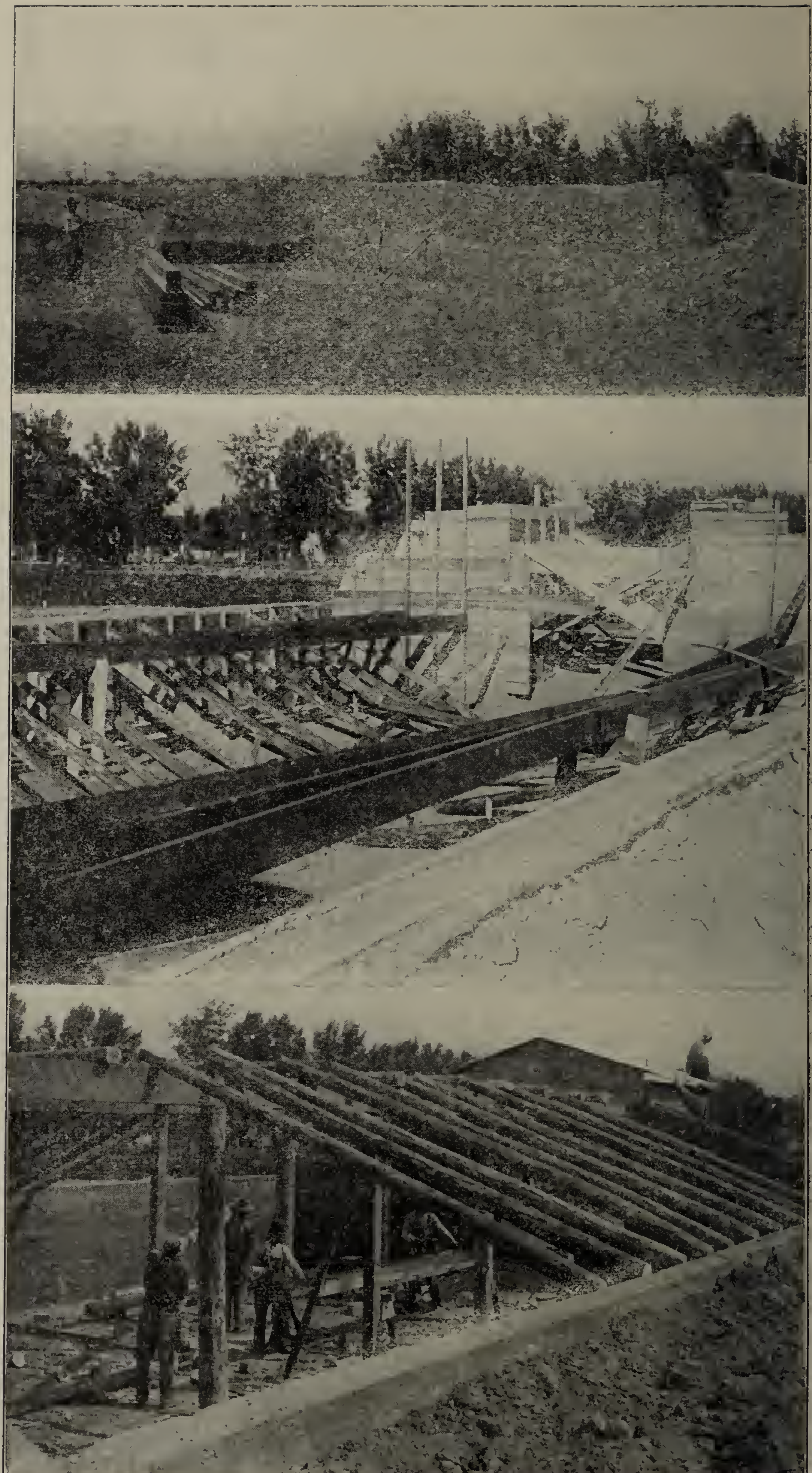


PLATE XVI.—The Station Cellar. Excavation. Braced Concrete Forms. Framing the Roof.

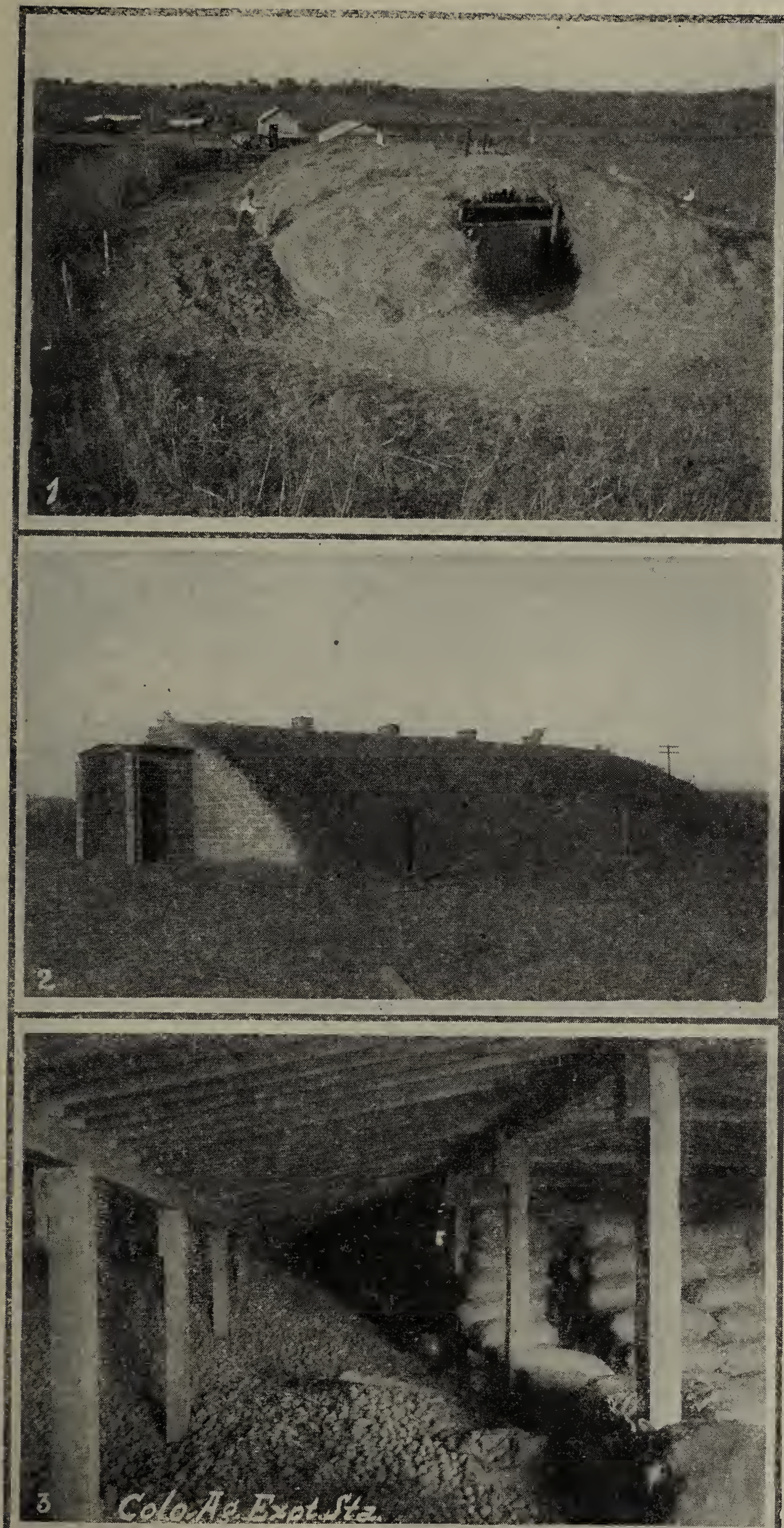


PLATE XVII.—Potato Cellars
1. Strawing. 2. Exterior. 3. Interior.

with top and bottom bolts rather than to a cross bar. Chains or straps and staples and pins should be provided to hold doors safely when they are to be left ajar; and some provision should be made to hold all doors securely open or shut to protect them from damage by wind and wagons.

The Roof is best made of dirt and straw, not alone for cheapness but because of their superiority as insulating material. In a rainy country a tight roof over the dirt might be required, although our dirt-roof cellars when in good shape leak only during prolonged and heavy storms. Even where concrete construction is used for the walls, it seems wise, as yet, to make a temporary roof, and to expect to renew it once in ten or fifteen years.†

Framing the Roof.—Rafters should be sound poles 4 inches at small end, set 15 inch centers, or 2 x 12 sawed stuff. Purlines should be built up of two or three 12-inch planks. Posts should be not more than 10 feet between centers at the most and should be at least 8 inches at upper end. Two rows are sufficient in a 36 foot room, but four lines of posts are required in a wider cellar.

Good Foundation for the posts and walls is required. The roof is extra heavy at times of rain when the foundation soil is liable to be soaked. Gravel or cobble stone bottom is firm but clay subsoils are often semi liquid when soaked, and on such foundation the largest flagstones are required beneath the posts and side walls.

Cost of the Experiment Station Cellar.‡—Gravel, 61 loads, \$76.50; poles, \$73.15; lumber, cement and paint, \$315.30; hardware, \$59.85, including square rods for reinforcing; sash, \$7.40; contract work for erecting forms, mixing and putting in concrete at \$3.25 per cubic yard, \$191.00; working foreman at \$4 per day and railroad fare from his home, \$87.20; straw, \$6; labor, \$332.85.* Total: \$1,149.25. See Plates XIV, XV, XVI, XVIII.

Farm Costs of a Similar Cellar.†—The cash expenditure on a farm for such a cellar will be reduced from the above by omitting charges for horse labor, by the use of efficient farm help, by the substitution of old digger chains for boughten reinforcement, and in

†Reinforced concrete over dirt and straw would make a permanent job, but is in the experimental stage, and is too expensive for trial by individuals.

‡The potato specialist built the cellar rather than let a contract, so he could keep an account of costs. For administrative reasons, the construction was delayed into potato harvest, and he was compelled to hire a competent foreman.

*This includes carpenters and painters at union rates, and team work at \$4 per day.

†The best farmers reckon cost of teams as well as of wear and tear on wagon and tools, cost of board and value of their own time, in calculating such a job.

other ways. A clever hard working farmer can put up such a cellar for a cash outlay of about $900; or if he omits the doors, vestibule, and bulkheads at one end, as he may very well do on a cellar of this size, his expenditure need not exceed $750.00. He may erect such a cellar and add a permanent water tight roof for about $900 cash out of pocket.

It Pays Best even with present prices of material to build strongly but cheaply, expecting to build over again when required. This is the business view: but a permanent structure like the station cellar appeals to the man who can afford it as a part of his farm home, for his own and his family's satisfaction.

Ventilation of Cellars is important, but is usually secondary to correct temperature and is ordinarily sufficiently accomplished in connection with air movement secured in proper temperature control.

The Cellar is for Cold Storage, and should be regarded as a place for maintaining proper and even temperatures. In the fall the ground is warmer than the night air, and this night air is our source of cold. In the spring, the ground is colder than the air except in the cool of the night and early morning, and at these hours we must get what ventilation and increase of coldness we can.

Late Evening and Early Morning attention is a requisite. On many fall and winter days doors need to be left open or ajar until, bedtime, and in the spring, doors must be kept tightly shut all day and cannot be opened until bedtime, and should be closed soon after sunrise.

Potato Cellars Close to the House are therefore much better than cellars in the field. The house, where possible, should be at the point nearest the shipping station, which is usually the trading town, in order to save any back haul of the heavy tonnage per acre produced by potatoes. The saving in time of grower and workmen in going back and forth to the cellar in the winter and spring, and the better control of temperature thus possible, more than offset in most cases the economy of team labor at harvest time effected by field cellars.

Correct Temperature for a potato cellar is just above freezing. Good management can hold it within two degrees above or below a standard of 34° F. all the main part of the winter; can get down to this standard quickly in the fall, if the cellar be close to the house; and can fight off the spring rise in temperature for a long time, but late evening and early morning attention are indispensable.

Thermometers Correct at 32° F. by test in slush of snow or chopped ice and water are required for this work, and should be tested before purchasing. The cheapest makes are all right, if so tested and found correct. Three at least are needed—one or more

PLATE XVIII.—Getting the Station Cellar Ready for Straw. End and Side Views of Completed Cellar. Photo by Sackett.

in the cellar, one outside at the cellar, and one on a post near the house.

MARKET STANDARDS: POTATO SHOWS.

A Higher Standard for Size prevails in Colorado than on the Chicago market. There a screen 1½ inches in the clear was standard until recently a 1¾-inch was adopted; here a screen 1⅞ inches in the clear is required, and a 2-inch screen is sometimes used.

Poor Sorting Bad Policy.—While it may pay the individual grower for the time being to sell poor and small potatoes and dirt, it does not pay the individual grower in the long run nor the district at any time. The general rate of consumption depends upon satisfaction and quality, and the market and price for any particular district depends very directly upon good goods and reliability.

Inspection Systems have been devised by dealers* for their protection, and by the Weld County Farmers' Club for the good of the Greeley potato district. While there are delays in getting any of these plans put into use, because the progressive element cannot lead the conservative element too rapidly, inspection is as sure to come as were pure food laws and the prohibition of chemical preservatives in canned goods.

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*The grades for potatoes in force under the Chicago Produce Reporter System are as below:

"Fancy Potatoes" shall be known as: One variety true to name, ripe, sound, smooth, clean, bright, free from disease, scab and second growth, uniform run of medium to large size, correct shape for the variety quoted, with none but would run over a 1¾-inch screen, and not over 5 per cent that would run through a 2-inch screen for round varieties. For long varieties there may be 20 per cent that would run through a 2-inch screen.

"Choice Potatoes" shall be known as: One variety, with not over 10 per cent mixture, but all of one color, ripe, sound, not over 5 per cent scabby, diseased and second growth, fairly clean, good color, medium to fair size and shape for variety quoted, with none but would run over a 1½-inch screen, and not over 10 per cent that would run through a 1¾-inch screen for round varieties. For long varieties there may be 20 per cent that would run through a 1¾-inch screen.

"Good Potatoes" shall be the same as Choice, only there may be a 30 per cent mixture of same color, or 10 per cent mixture of any color and variety, fairly well matured, according to season shipped, and not over 15 per cent scabby, diseased and rough, fair to dark color, fair size, with none but would run over a 1-inch screen, and not over 15 per cent that would run through a 1¼-inch screen, with not over 2 per cent unsound.

"Field Run Potatoes" should be practically sound, but unassorted.

Dockage, when loading potatoes.—In cases where the percentage of dirt, small, inferior, green, etc., potatoes, exceeds the allowance in above grades, inspectors may make said stock equal to the grade quoted, or purchased, by such dockage as they consider equitable.

The section from which the potatoes are quoted, and the general quality of that season's crop in that section, should always be considered in connection with grades; not as really changing above definitions, but in close cases inspectors should favor the shipper if that season's general

One of the Systems for Dealers is operated by a house which also publishes a produce paper and a book of commercial ratings. Where shippers agree to put the system in force at their point, all produce is inspected as loaded by the inspecting company, while its adjusters also operate in the consuming territory, so that unreliability and trickery are largely eliminated. The curbstone shipper and the shortsighted grower who sells to him are the hindrances to the success of this system.

The Weld County Farmers' Club Scheme, in force for the crop of 1909, and considered unnecessary because of the fine quality of their 1910 crop is this: The Club does the work and hires a chief inspector at $100 per month, and sub-inspectors at each loading station, paid by the car. The dealers' association, which receives the first benefits in reliability of goods handled, pays the expense. Certificates are furnished for each car inspected.

Potato Shows should be so arranged that the judge does not know the name or location of the exhibitor.‡ Potatoes should be shown in wire baskets in two tiers. To each basket a tag should be fastened bearing the number of the entry and the name of the variety. On each basket should be laid a card with name of exhibitor and all particulars. Until after the potatoes are judged, this card should be sealed in an envelope bearing the number only on the outside, in addition to the score card, if used, printed thereon.

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crop is not up to the average quality, or favor the receiver if as good or better than usual.

MARKET GRADES: The Weld County Farmers' Club

Fancy Potatoes.—One variety, ripe, sound, smooth, clean, bright, even run of good size, true to type, not over 5 per cent but would run over screen two inches in clear.

Choice Potatoes.—One variety, ripe, sound, not over 5 per cent scabby, wormy or knotty; fairly clean, bright and even in size; not over 10 per cent but would run over screen two inches in clear.

No. 1 Grade.—One variety with not over 5 per cent mixture of same color, or 2 per cent of other color; fairly ripe for date of shipment; not over 15 per cent scabby or wormy; not very knotty or muddy, fair size, run over screen 1⅞ inch in clear.

No. 2 Grade.—Not over 50 per cent scabby, wormy, knotty or green. Not over 5 per cent unsound or that would go through a screen 1⅞ inch in. clear.

Disqualifications for show or first three market grades. Screen less than 1⅞ inches in clear. Many knots. Very deep eyes or very irregular shape. For show, any mixture of varieties; for market more than 5 per cent of same color or 2 per cent of different color. Color mottled, splashed, blue or purple. Muddy. Over 15 per cent scabby or wormy or 1 per cent unsound. One-fourth hollow. Sacks not neat, strong, uniform in size. Sacks not securely sewed with standard sack twine.

Trueness to name and type required. No red potato to score as high on color as a white variety; no deep-eyed or long potato to be scored as high on shape as round and smooth.

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‡This is best in any case, and is the only system under which the potato specialist will act as judge.

PLATE XIX.—A POTATO SORTER; and an unsorted sack—one-third smalls and dirt.
ARRANGEMENTS FOR A POTATO SHOW, with cooking tests for sweepstakes.

The Score Card of the Weld County Farmers' Club is as follows:

I. Dealers' Scale.

Size 20	Too large	4
	Too small	10
	Not even	6
Shape 10		10
Skin 40	Not bright	10
	Dirty	10
	Scabby or wormy	20
Quality 30	Unsound	10
	Brittle or spongy or green	20
		100

II. Final Purchaser's Scale

Smoothness	5
Pares thin	10
Flesh white	5
Sound and not hollow	10
Cortical thick	10
Centers small and not watery	10
	50

III. Consumer's Scale

Quickness of cooking	5
Potatoes cook alike	5
Mealiness	10
Whiteness	10
Grain (mashed)	5
Flavor	15
	50

Total Score (perfect 200).

Cooking Tests should always decide the sweepstakes prizes. Growers and the potato specialist alike owe this to their own interests and that of the consumer. Six uniform white enamel pots tagged or numbered, and gas or gasolene stoves to boil six lots at once, together with paring knives, basins, a potato ricer or fruit press, and one or two capable assistants are required for doing this work with dispatch.

EFFICIENCY OF LABOR IN POTATO HARVEST.

Labor Costs More in New Regions.—We have been struck by the low efficiency of labor in the potato harvests of our newer regions as compared with our established potato districts; a difference almost as great as between the labor cost of shoes made by a cobbler and by a factory, and for much the same reasons.

This slowness is a disadvantage, not alone in cost of production, but in increased danger of being caught by a fall freeze.

System and the Best Equipment are Cheapest.—For economy and speed the best sorters must be used; and solid sacks—"Liverpool Returns," the best wire baskets, the best needles, and a high grade of Italian sack twine are none too good. Standard potato wagons are absolutely necessary to the grower who would make most money.

The work should be systematized, and each man have his job. The digger man should feed and clean his horses, and then have his breakfast while others harness the horses, so the digger can run at daylight.

A Day's Work.—In potatoes yielding 12,000 pounds per acre, each picker should put on the sorter not less than 8,000 pounds per day, of nine or ten hours. Where the yield is larger and made up of big potatoes, 12,000 to 15,000 pounds are sometimes picked by a good man; and the grower should be willing to see such a picker in such potatoes make $5.00 a day. It pushes the deal along, and is worth the price, being often cheaper than day labor at $2.00 or $2.50.

In cutting potatoes, 1500 pounds well cut is a good day's work, and 2500 requires a remarkable pace. In planting, four to seven acres should be put in with one planter per day. In sorting up and

PLATE XX.
Three Tons is a Standard Load of Potatoes for a Standard Potato Wagon

sewing good potatoes in the cellar, fifty sacks or 6000 pounds is a fair day's work per man, although expert crews have done three times that amount.

HORSES FOR POTATO FARMING.

Some Farms Can Use Heavy Horses.—The size of the draft animal for a potato farm is set by the work to be done. While 1,600 to 1,800 pound horses are very desirable for breaking alfalfa and for hauling big loads, such animals are a damage in cultivating and digging, and are undesirable on long hauls because they cannot be trotted on the return road and last. Such horses are the thing for the grower close to the railroad switch, who plants wide. Aside from other considerations the smallness of mules' feet and their

narrowness of tread recommend them, especially in the heavier weights, in preference to horses, for potato growers.

An Active 1500-pound Animal the Best.—Horses of not too blocky type, weighing from 1,400 to 1,500 pounds, are the choice of most experienced growers. Five or six such can break alfalfa anywhere; four such can pull a digger all day, if required; and a pair of them can handle three tons of potatoes for the regular load on good roads. This is the standard, net load, at Greeley.

Power Units.—An eighty-acre potato farm should have five horses of this size, and a 160-acre farm, eight. It is cheaper to have them good, and to have only this number; and it is wise to adopt a standard of size, action, color, and harness, and to have only such animals and harness, in order that the units of power may be interchangeable, and make up into two, three, four, five or six-horse teams, of like strength and speed.

The Manufacturer has long considered such items as these in the efficient conduct of his business; farmers have commenced to apply the same principles to their business.

FIELD EXPERIMENTATION

Variety Trials have been continued by the station since 1906 and before. All promising sorts of this country, Great Britain, and of continental Europe have been tried. We feel that we know absolutely the best sorts for Colorado. This work is therefore finished to date, and will be continued only as new sorts arise. It is greatly to the economic benefit of the potato industry to have such work done by the state, and the facts established by clear cut public experimentation rather than by widespread, indefinite and costly private experience.

Seed Changes and Sources are now pretty well understood. The principles involved have been largely fixed, and are formulated in Bulletin 176, and such work as is carried out in the future along this line will be only by way of working out these matters more definitely.

Some New Terms have been adopted in Bulletins 175 and 176. From England we have appropriated the term **ware**, which we think a more useful term than **saleables** or **table stock**, both of which it can well replace. We have used also the English word **maincrop** instead of our indefinite term **late varieties** as opposed to **early varieties.** For instance the Pearl potato is our leading **maincrop** sort, but it is not a late potato. Among variety names we have attempted to establish the better and more appropriate names, always favoring the old as opposed to any new name. The **Peachblow** should not be called McClure; the **Cobbler** is not properly called Eureka; and **Russet** we believe to be most appropriate for the promising new sort which has carried the indefinite names White Beauty and Russet Burbank. Parts of tubers are more definitely named than heretofore, in Bulletin 176.

Future Field Work should be in the development of varieties and strains; in obtaining further knowledge as to the reasons for yield and for running out of seed stocks; in carrying along up to date each year variety trials that we may always have the best; and in the promotion of dry land potato growing for the benefit of the entire potato industry and for the general good of dry land agriculture. Funds permitting, a demand for fertilizer trials at Greeley and Carbondale should be heeded in 1911 and 1912.

One One-Hundredth Part of an Acre is in nearly all cases the basis for the yields given herein. The rows for weighing were in most instances taken alongside each other, and are believed to afford correct and fair bases for judgment of the points in question.

The Potato Specialist, primarily the technical servant of potato growers and consumers, like an engineer to other industries, is used also by the

PLATE XXI.
Assistant Chisholm and Harvesting Kit at Parshall up the Moffat Road.

state as a counselor in person and by correspondence in the development of its newe · districts. While not a teacher, his work is best managed by the Agricultural College. He is a gatherer of information and experience for the benefit of all growers of potatoes, and as such he is a worker in farmers' institutes, where as in bulletins he renders his reports. The far sighted policy in Colorado that has made this work possible, going hand in hand with our natural advantages, must result in a leading position for Colorado among potato states.

STAND

How to Count Stand.—Count 100 hill spaces, as near as can be estimated, including both present and absent hills. Count the skips back and deduct the number from 100. The result is the per cent. of stand. This method is both simpler and as accurate as to measure with a tape the calculated distance for 100 hills and to count the hills present therein as the per cent. of stand.

Causes of Poor Stand.—There are six main causes in Colorado for loss of stand of potatoes: (1) Dryness of seed bed. (2) De-

fective seed or seed asleep. (3) Disease or rot. (4) Defective planting. (5) Large and uneven or poorly cut seed. (6) Cultivation.

1. *Dryness of Seed Bed.*—The upper picture Plate XXII shows a potato field the near part of which had been used for a sheep feed lot the second winter previous and was cleaned up only in time to plow. The pens had been hard tramped and thoroughly dried down deep, while the bents had been well mulched with the litter of the hay, and were in good moisture condition. Potatoes will *sprout* without moisture, but they will not *root* unless moist earth touches the seed piece. Therefore, summer fallowing, fall plowing with spring tillage, or irrigation before plowing, or ditching and irrigation before or after planting, are absolutely necessary to be sure of stand. Potatoes must be planted deep enough for the moisture level to remain in touch with them even if the surface dries after planting.

2. *Defective Seed or Seed Asleep.*—Seed that is slow, from drying, heating, over sprouting or disease may rot before it roots well, so that the little plant loses the impulse of the food in the seed piece. Late varieties may partially recover from such a set back but early sorts cannot. Seed potatoes should be held asleep by cold storing but should be awakened in time to be ready to grow when planted. In moist soil five days from planting we have noted on potatoes that had stubby sprouts when planted, roots three inches long, while similar seed that had not started or had had the sprouts broken off showed roots only 1 to 1½ inches long. *

3. *Disease or Rot.*—Potatoes affected with *Fusarium* will often rot completely before the plants get a good start, or before they start at all. This is particularly true if the seed bed be dry and rains come *after* an interval. And such plants as do start are often killed by the disease soon after or even before they come out of the ground. †

4. *Defective Planters and Planting.*—Not less than 15 per cent. loss in stands the state over is due to this cause, and for the most part to the sort of defective pickers shown in the right of the illustration, Plate XXII, which let go the seed piece in the hopper, instead of holding it, as do those to the left, until the seed piece is

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*The greenhouse picture Plate XXII shows one row of Pearls in pots that had been held warm long enough to wake them up ready to grow, and two rows of pots with the same kind which were still dormant when planted on the same date. The plant that establishes itself quickly is much surer to grow and to do well.

† Some experiments indicate that the rotting of seed may be partially controlled by the use of lime on the seed. This is a matter which we hope to take up thoroughly in 1911 and 1912. Rotting of seed already reduces our potato output in Colorado at least $200,000 yearly.

dropped into its place in the ground. We find 95 per cent. of perfect work quite obtainable from our leading planters of either type. The best picker type requires one man who absolutely knows his business. The other type requires a good driver and a faithful, quick and everlastingly patient man or boy behind. We find that one planter crushes the seed about the same as the other, and that one can do as good work as the other. The choice should be made according to the help available. Compare the stands obtained on Pearls at Parshall and Montrose with a picker planter, with those at Carbondale and Greeley, where the other type was used. The annual loss, about a quarter million of dollars, due to defective planters, largely a matter of easy repair, is twice the first cost of the 2,000 planters in use in Colorado.

5. *Large and Uneven Seed.*—Very large seed does not drop as well and is more subject to rot and always results in poor stands. It pays to screen seed to even size in two or three lots, and to cut evenly and carefully, to secure even dropping by the planter. A few large pieces in the hopper are a continued source of lost stand while they remain. It goes without reminder, that seed should not be sliced long but cut as nearly square as possible and always with good eyes in each piece. It pays to use seed weighing as much as two ounces to the piece, and the best stands are always obtainable by using whole seed of this size.

6. *Cultivation.*—The close, deep cultivation required in our heavy and flat lands to combat disease is a frequent cause of large loss in stand, especially in new regions where employers do not realize that potato cultivation demands a high grade of skilled labor and the best tools, as well as accurate planting and straight rows evenly spaced.

ACTUAL LOSSES BY POOR STAND.

Part of Loss Offset.—The following table shows just how much of the loss in hills missing is made up by the hills to each side of the empty place. We find the weight made up much less than some growers have supposed. The first hill on one side of a skip, we call *Firsts.* The next hills we call *Seconds, Thirds,* and *Fourths.*

How Affected by Distance in Row.—When the best distance in the row has been decided upon for the variety and soil, the loss by defective stand appears to be independent of the distance used in the row.

CONCLUSIONS.—From the weight of these 802 hills dug by hand and carefully weighed, as summarized above, we may conclude:

1. Skips in some varieties affect stand to the second hill to

each side, and large skips sometimes affect more than do single skips.

2. Small plants (early varieties) cannot make use of much extra root space; and loss of stand with them gives an almost equal loss of yield.

3. Deep rooting plants like Rurals and Carmens may or may not make use of extra space. There seems to be no uniformity as to the effect of stand on per cent. of culls.

4. If the weights of the thirds and fourths be taken to repre-

Weights of hills dug by hand bordering skips in stand.
Pounds and tenths.

Place	Variety	Sets of hills	Average Firsts.	Average Sec'nds	Average Thirds.	Remarks: Screen 1⅞ in.
Del Norte	Sunlight	20	2.3	1.7	1.7	Planted 10x36 inches. Firsts 10% culls, others 16% each.
	Six Weeks	20	1.4	1.3	1.02	
	Noroton	10	1.12	1.14	...	6% and 19% culls.
	E. Ohio	10	1.2	1.1	.92	Uniform % culls.
	Cobblers	10	1.7	1.4	1.2	Firsts & thirds same % culls.
Skips of one hill	Pearls	10	1.4	1.9	1.4	Culls 10%, 5% and 6%.
Skips of 2 or more	Pearls	10	2.2	1.5	1.2	Culls 10%, 10% & 11%.
	Carmen III	10	1.8	1.6	1.5	Fourths 1.5. Culls 10%, 6%, 19% and 20%.
Montrose	Rural No. 2.	30	2.3	1.8	2.0	Fourths 2.1.
Skips of 2 or more	Same	30	2.5	...	...	Planted 12x39 inches.
Kersey	Pearls	20	2.3	2.3	2.1	A yield of 24,000 lbs.
Greeley	Carmen III	18	1.4	1.7	1.1	Fourths 1.3 lbs.
	Carmen III	15	2.0	1.6	1.3	Fourths 1.2. Planted 15x38.
	Blue Victors	20	1.6	1.3	1.3	Fourths 1.1. Yield 14,200.
	Rural No. 2.	15	2.0	1.6	1.3	Fourths 1.2.
	Average of 248 sets of 3 & 4 hills..		1.8	1.6	1.3	Fourths 1.4.

sent the average yield per hill in a perfect stand, then the firsts and seconds recover together an average of .35 pounds, or about ¼ of the loss of one hill.

5. A similar amount is made up on the other side of the skip.

6. *The hills on either side of a single skip make up one half the loss.*

7. *The skips of more than one hill are positive losses of yield except for the weight of one half of one hill.*

STANDS IN GROWERS' FIELDS.

Average Stands 70 to 75 Per Cent.—An extensive examination of stands in fields over the state, in growers hands, convince us that among Pearls and Rurals which constitute nine-tenths of our output, 70 or 75 per cent. is an average stand. An examination of stands secured with these varieties on our plots will convince the reader that a stand of 85 to 90 per cent. is attainable in field prac-

PLATE XXII.—Some Factors Affecting Stands.
1. Condition of Seed Bed. 2. Picker Points Good or Bad. 3. Seed Awake or Dormant.

tice. Growers have told us they had fine stands, when accurate count showed as low as 70 per cent.

One-Fifth Colorado Crop Lost.—Thus there is a loss of about one-fifth of our crop annually by poor stand, or *half at least of the profits.* The Colorado crop has a minimum value of over $4,000,000. One-fifth this amount is $800,000.

Possibilities of Economic Benefits.—If there can be saved, by educational work and by accurate statement of the facts, one-eighth of this $800,000 for one year, or $100,000, the interest on the saving for a single year, at 5 per cent. annually would support permanent technical work for the potato industry. If one-fifth this loss can be saved annually, it would support the agricultural college in all its branches.

LOSSES BY DEFECTIVE STAND

In per cents of whole crop for stands running from 50% to 95%.

Per cent. stand	Typical skips for each stand stated in left hand column. For every skip ½ hill is made up at sides, the rest is absolute loss.	Stand lost, per cent.	Basis of 100% stand or 100% crop.	Crop lost—per cent on crop secured. 90% standard.	85% standard.
95	5 of one hill each	5	3	0	0
90	8 of one hill each and 1 of two hills	10	5	0	0
85	9 skips of one hill each and 3 of two each.	15	9	4	0
80	10 ones, 2 twos, 2 threes	20	13	9	5
75	13 ones, 3 twos, 2 threes	25	16	13	8
70	12 ones, 4 twos, 2 threes, 1 four	30	21	20	15
65	12 ones, 4 twos, 2 threes, 1 four, 1 five	35	25	27	21
60	14 ones, 1 two, 2 threes, 2 fours, 2 fives	40	30	36	30
55	10 ones, 11 twos, 3 threes, 1 four	45	33	42	36
50	14 ones, 5 twos, 1 three, 2 fours, 3 fives	50	37	51	44

With very early sorts, loss of stand means nearly a proportionate loss in yield, and is much more than is above shown.

Figuring how much he loses by a poor stand, a grower should decide what stand he should secure: 85 or 90 per cent. Then take the line of the table where he finds at the left the stand he actually secures, and in the columns to the right, under his standard stand, he will find his loss in crop, on the basis of what he secures. He will thus be able to figure how much expense he can afford to incur to care for seed and seed bed and to repair old or buy new planters.

DRYLAND POTATO GROWING: Points of Difference from Other Potato Culture

Cheyenne Wells 1910.—The yields here represent the minimum of what need be secured on suitable soils in the plains region. The land was native sod in 1894. It has been farmed each year since, without manure or rotation with peas, nor has it been summer tilled or fall plowed. The natural conditions both of soil and of season could hardly have been worse than in 1910. First class care and tillage with first class seed made a yield that would at least supply food, to a farm home, on the plains.

Rotation with Peas, Beans and Alfalfa.—The results at Julesburg hold out a promise of large yields to the grower who will rotate with

legumes and summer till for potatoes. Pea and oat hay is good hay to produce milk, and if planted early on rightly managed land is a sure crop. Mexican beans are a paying dryland crop. The great interest in good alfalfa seed is sure to result in profitable growing by drylanders of special varieties of alfalfa for seed purposes. And rotation with peas or beans and with alfalfa when it has to be plowed up will increase all the farm crops on the plains. See **Julesburg 1910, herein.**

Plowing for potatoes will be done the summer before; or, after summer tilling, will be done in the fall. Spring plowing is a gamble. Fall and spring tilling will be universal. Summer tilling will promote good shape in the potatoes grown the next year.

PLATE XXIII.- Planting 2 acres a day with a planter costing 98c Chicago. $1.25 Denver.

Planting is well done deep on the dryland and is one of the things upon which good shape, early set, and good seed depend. It is not advisable to plant with a plow. Use a horse planter or plant as deep as possible with a hand planter.

Cultivate Shallow following cross harrowings. Do not cultivate when it is not needed, but keep out all the weeds and break every crust.

Machine Diggers of the four horse elevating type are often too expensive for dry land neighborhoods while plows are too wasteful of potatoes. The double beam rod shaker digger shown in the cut is a good compromise, as it is cheap and works well on small or mature vines when the ground is loose and not wet.

DEL NORTE

The Good Yields secured at this point commend the soil and care in a year below average for the yields of the valley as a whole. The blights and diseases which in 1910 hurt the earlier sorts, even including Pearls, left our Rurals by far the heaviest yielding class. The yield of the Dewdrops (Stake 150) maturing with Pearls we discard because of the undesirable shape of the tubers. The net weight of the Cobblers and the gross weight of the Ohios were about the same, and both were here of fine table quality, and were ready the first of September. All varieties were dug September 21, and at this date Rurals though thin skinned were mealy and white fleshed.

The Productiveness of Sports such as Red Ohios from White, White from Red, Blue Pearls from White, or White from Blue is illustrated at Stakes 169 and 170.† This has been specially noted with Pearls, and we

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*One of the representatives in our present legislature cites his experience that potatoes planted in the furrow that dries out over Sunday give very poor stands. The same is true to some extent of all furrow planting.

†See herein **Mixing in the Hill.**

often hear growers say that they wish they could raise Blue Pearls because of the yield. Sports of this sort afford a good starting point for improved strains, but we do not find the increased yield is long maintained of itself. We have secured here, at Greeley and at Montrose, from dry land Blue Victors, by means of good conditions and the liberal use of manure and artificial fertilizers to induce variation, about 150 pounds of new White Pearls, to be used at Carbondale in starting an improved strain of Pearls.

Close Planting on deep soils here results in great increase of yields and most desirable uniformity of size. Note the yields secured from stakes 200 to 190. Deep rooting sorts like the Rural respond the best to this practice. Note that the use of double the seed, or 1000 pounds more per acre, is more than doubly returned in the small seed secured in the crop, and a profit in the ware averaging, on the six lots of Rurals 3049 pounds per acre, for the five inch instead of 10 inch planting. The much more saleable uniform crop is also to be remembered.

Source of Pearl Seed for the San Luis.—Note the difference in the same pedigreed stock of White Ohios, one lot kept the last year at Greeley and the other lot at Pagosa Springs. The ware yield of the latter is double the former. Note the same with Pearls the sixth year at Greeley on the same farm (176) or that the sixth year at Pagosa (175), and compare again with 173, changed to another farm at Greeley the last year before coming to Del Norte, and with (200) the yields of big Del Norte grown seed which gave a very poor stand. Compare also the yields from first, second, and third year Greeley Pearl seed, remembering that of this seed secured in the same neighborhood the "first year" was much the poorer.

CHEYENNE WELLS—1910

May 7-9: Planted 24x36.

Stake	Variety and Source	Total
37	Pearl—Divide	1403
38	Pearl—3 yr. Greeley	1422
39	Pearl—2 yr. Stove P.	2848
40	Pearl—1 yr. Greeley	1564
41	Pearl—10 yr. Stove P.	1754
42	Pearl—Montrose	1228
43	Cobbler—Akron	1020
44	Cobbler—Maine	1709
45	Cobbler—Mancos	1719
46	Carmen I—Maine	1916
47	Peachblow—Flagler	2455
48	E. Ohio—Maine	2286

These were planted by hand, under excellent conditions, and the stand was practically perfect, except for damage in cultivation.

San Luis Valley Profits in potato growing **depend on the seed** secured. First year Greley seed is much better than that longer at Greeley; seed grown at Pagosa or Del Norte from Greeley or (presumably) from dry land or Wisconsin seed is much better still. By the results with Rurals, a strong presumption is raised that Pearl seed raised by close plantings of the best Pearl seed brought to Del Norte will run enough to seed size so that the rest of the valley may well look to Del Norte as a source of seed, provided only and always that the parentage of the seed offered be known.

Conditions and Parentage: not Place alone are to be considered in the matter of seed changes. To no potato growers of Colorado are the principles underlying these matters more important than to those of the San Luis. See Bulletin 176.

DEL NORTE YIELDS PER ACRE*

In Pounds.

Screened over 2-in. screen and corrected by 3 per cent. estimated difference to 1 7-8 basis.

Stake	Variety and Source	Total	Ware	Culls	Stand
147	Sunlight—Maine	11460	10270	1190	84
157	Six Weeks—Maine	10975	9107	1868	88
151	Bovee—Maine	12240	11136	1104	63
192	Noroton—Maine	5790	4971	819	59
150	Dewdrop—Maine	20740	19661	1079	81
148	Burpee—Maine	12260	11186	1074	73
152	Ohio—Minn.	11088	8562	2526	88
153	Ohio—Divide I	10220	8734	1486	81
158	Cobbler—Maine	12080	10266	1814	75
159	Cobbler—Minn.	12414	10427	1987	83
205	Ohio—Divide II	9540	8385	1155	76
154	W. Ohio—Pagosa	13271	10217	3055	85
155	W. Ohio—Greeley	10350	5174	5176	82
191	White Victor—Del N.	14594	13736	858	..
169	White Eye Pearl—	22806	22404	402	..
170	Purple Eye Pearl—	20700	19251	1449	..
160	R. Seedling—S. Prairie	8100	7323	777	80
161	R. Seedling—Greeley	9540	8386	1154	81
162	R. Seedling—Carbondale	8600	6658	1942	83
163	R. Seedling—Divide	7400	5622	1778	78
168	Russet—Carbondale	7740	6112	1628	..
164	Snowflake—Greeley	9480	6604	2876	89
167	Challenge—Greeley	8040	3301	4739	87
180	People's—Greeley	9440	7953	1487	91
166	W. Prolific—Pagosa	6640	5159	1481	77
172	G. Mtn.—Greeley	8400	5692	2708	88
202	P. of Canon Valley	9600	7168	2432	81
171	Wells'—Wheatland	4680	3434	1246	83
165	Peerless—Greeley	14240	11267	2973	88
176	Pearl—6 yr. Greeley	8240	5927	2313	86
175	Pearl—same, Pagosa	13600	12728	872	78
181	Pearl—1 yr. G. sod	11440	8703	2637	88
179	Pearl—2 yr. Greeley	10080	7742	2338	87
174	Pearl—3 yr. Greeley	9760	7642	2118	89
177	Pearl—1 yr. Greeley	9960	8258	1712	84
173	Pearl—6 yr. Ped.	9280	7398	1882	79
178	Pearl—1st. yr. Ft. Collins	11360	9340	2020	91
182	Pearl—Wisconsin	12320	11249	1071	81
	Same	12800	12384	416	..
200	Pearl—2 yr. Del N.	18000	16210	1790	65
	Same, poorer soil	12550	11776	770	..
	Same, next row 2x10	14700	12241	2459	..
189	Carmen III—Wis.	12840	11295	1545	74
	Same, 2x10	17760	13512	4248	..
188	Rural—1st. yr. Ft. Collins	13080	11192	1888	75
	Same, 2x10	15480	12464	3016	..
187	Rural—1st. yr. Greeley	12240	9967	2273	81
	Same, 2x10	19680	14990	4690	..
185	Rural—Greeley, sod	19920	15178	4742	..
	Same, 2x10	17980	16039	1941	..
183	Rural—Wisconsin	16502	.....	....	75
	Same, 2x10	17710	15931	1779	..
184	Rural—1st. yr. G., alfalfa	17958	14437	3521	71
	Same, 2x10	22965	19721	3244	..
186	Rural—Greeley, station	15625	13593	2032	82
	Same, 2x10	19800	18234	1566	..
190	Peachblow—Greeley	15000	12810	2190	75
	Same, 2x10	21000	16520	4480	..
156	E. Ohio—Parshall	10800	9564	1236	82
206	Triumphs—1st. yr. Del N.	15240	14017	1223	75

* The planter used here caused a loss of stand of about 10 per cent.

MONTROSE: BOSTWICK PARK

Planted: Earlies 12x39. Late Varieties 10x39.

Stake	Variety and Source	Total	Ware	Culls	Stand
	Earlies on sage brush land in orchard.				
64	Dewdrop—Maine	4550	4300	250	95
56	Noroton—Maine	1600	1300	300	60
66	E. Ohio—Red River	3300	2600	700	95
57	Triumph—Carbondale	4800	4300	500	76
58	Same—Salzer's E.	.....	.....	....	76
59	W. Bliss—Maine	4000	3600	400	72
65	Perfection—Maine	5300	4700	600	63
67	Bovee—Maine	4300	3700	600	67
63	Burpee—Maine	5000	4500	500	45
62	Cobbler—Mancos	5700	5200	500	90
61	Cobbler—Red River	5500	4100	1400	77
	On four year old alfalfa sod.				
84	B. Victor—Nebraska	15800	15500	300	95
87	Cobbler—2x10	7000	5500	1500	..
70-a	Duplicate	7550	6050	1500	..
69	Snowflake—B. P.	15000	14000	1000	100
68	Snowflake—Greeley	16300	14300	2000	96
77	"La Follette"—Wis.	13250	12750	500	93
70	Pearl—Pedigreed	12200	11700	500	94
73	Pearl—Stove P.	15300	13700	1600	77
71	Pearl—B. P.	13100	12500	600	91
72	Pearl—Carbondale	9600	9300	300	87
76	Pearl—1 yr. G.	10600	9700	900	94
75	Pearl—1 yr. G. sod	13300	12300	1000	94
74	Pearl—Del Norte	16000	15700	300	94
81	Rural—B. P.	13700	13100	600	96
83	Rural—Eaton	16400	15800	600	95
80	Rural—Greeley	14700	13700	1000	98
82	Rural—W. Sprout	17000	15000	2000	93
79	Carmen III—Wisconsn	18600	17400	1200	92
78	Downing—Montrose	12500	11600	900	95
85	Peachblow—Greeley	12000	9500	2500	93
86	Peachblow—Carbondale	14100	11100	3000	88
87	Russet—Carbondale	12900	10400	2500	93

Earlies here had a poor start due to deeply dry soil and, as at Greeley, to drouth. And early potatoes cannot make up for lost time, as is noted under the division of this bulletin **Early Potatoes**. The excellence of the Triumph and the Cobbler are corroborated, and on the alfalfa sod increased yields were obtained from close planting of Cobblers.

Maincrop Potatoes suffered severely not from a poor start, for they had a good one, but from the breaking of the ditch and dryness in mid-season. The large yields of both lots of Snowflakes as compared with others is a feature, while the Downings and Russets again give good yields as secondary sorts.

Among the Pearls, note the capacity of the Stove Prairie dryland seed to give a good account of itself in hard conditions, as was shown with dryland seed Pearls at Greeley. This same idea applies to the Bostwick Park sage brush land Pearls,† the Greeley sod Pearls, and possibly to the Del Norte pea land Pearls as compared with those grown on alfalfa land at Greeley and Carbondale, and it is a general principle, that good seed does better when taken to richer conditions than those under which it grew.

†See results with Bostwick Park sage brush land seed at Julesburg and Greeley, and of Parshall sage brush land seed at Greeley. Sandy land with enough slope and the early irrigation possible at high altitudes, we believe to be factors in the success of this sage brush land seed.

Among Rurals, note that all imported stocks exceed the home seed, and that a Rural seedling, Carmen III, Wisconsin grown, leads them all, while seed, pear-shaped, grown at Eaton near Greeley comes second. This seems to argue for change of seed stocks in this locality.

White Sprouted seed is found among all the Rurals of the Montrose district that we have seen, and their white blossoms are conspicuous among the purple in the fields. This is a serious defect to the eyes of a potato man in the otherwise wonderful Rurals shipped from the Uncompahgre, and we thought to find that a selection of the white sprouted sort at planting time would show a lower yield. Such is not the case. They exceeded the Rurals from the same lot by 3300 pounds gross per acre and by 1900 pounds net. Their shape is, however, inferior and is still worse in poorer conditions.* The white sort is doubtless Carmen I. See its yield at Greeley.

CARBONDALE

Record Yields for unmanured, unfertilized field culture were here obtained on our plot. Such was the uniformity of yield at the upper and lower ends of rows and from one side of the field to the other, that we believe that the whole piece would have gone the same as any part if planted to the same sort.

Early Sorts.—Note the 2800 pound increase in the Cobbler yield by the 5½ inch planting (A and B) and that at stake 128 the very earliest sorts were made to yield 20,000 pounds per acre by planting in 20 inch rows and cultivating with a beet cultivator.† The excellence of the Russet as an early potato is here as elsewhere strongly indicated. (Stakes 129 and 130). Note also that it responds here strongly to seed selection. The more oval seed produced 6257 pounds more ware per acre than the slim seed.

The Snowflake has been a famous potato. Believing that the great work done by Carbondale growers with the Peachblow and the Triumph could be repeated with the Snowflake, we sorted over a large quantity of Greeley Snowflakes, and planted the best, to be hill selected here, and then grown on the dryland, to be thence supplied in 1913 to all the State, as a home favorite potato. The yield (S. 126) promises success.

The Pearls, especially the locally developed Pearl, called Valley Prize, gave remarkably high net yields, without knots, cracks, hollowness or other defects. Stake 134 had a net yield over 1⅞-inch screen of 598 bushels, and the next highest net yields were of Pearls from Pearl seed grown in the valley at Carbondale, and at Greeley, and from Messrs. Sweets' Peachblows and Gold Coins.

That Rurals were Omitted from the Carbondale lists is one of the oversights of a strenuous season. This variety now leads all others in the United States. From what it does at Del Norte and Montrose and in private hands at Carbondale, we do not hesitate to recommend it for planting beside the Peachblow as a **late sort.** It will doubtless lead all other white potatoes in yield, uniformity, beauty,‡ and high quality at Carbondale. For **medium,** the Pearl will be standard. For **early** the Russet and the Cobbler promise to be standard. We would not at Carbondale go outside this list. It has been a misfortune that all varieties do well here.

Close Planting will be the thing for Rurals, as close as four inches perhaps. At 124, note that the Peoples gave a good profit on using twice as much seed, and that when three times as much seed was used it returned in the crop. This 3-2/3 inch planting also gave a much increased percentage of seed size. Compare also Pearls so planted at stakes 138 and 139, where the closest planting reduced the yield but produced more seed. See also Del Norte for close planting of Rurals and Peachblows.

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*The new sage brush lands of the Uncompahgre should develop a trade for seed Rurals but will find that pure seed will be demanded.

†See **Early Potatoes,** a division of this bulletin.

‡Rurals come out of the ground clean because of their smooth skin.

CARBONDALE—1910

Planted 11x38. 1 3-4 Screen used and corrected to 1 7-8 basis by addition of 2% to culls.

Stake	Variety and Source	Total	Ware	Culls	Stand
A	Cobbler—11 in.	18100	15928	2172	93
B	Cobbler—5½ in.	20900	.....	....	93
C	Sunlight—Maine	28600	.....	....	97
D	Dewdrop—Maine	31600	.....	....	100
E	Perfection—Maine	17789	.....	....	90
128	Earlies—11x20,Noroton	22040	17632	4408	..
	Triumph	18810	15048	3762	..
121	Late Ohio—S. P.	20700	.....	....	85
122	R. Seedling—Carbondale	26642	.....	....	91
123	R. Seedling—S. P.	24200	.....	....	91
124	People—Carbondale	27785	.....	....	96
	Same, 2x11	32393	.....	....	..
	Same, 3x11	33529	.....	....	..
126	Snowflake—Greeley	24600	19434	5166	97
127	F. Snowflake—Maine	34200	.....	....	96
129	Russet—Carbondale	28484	25353	3133*	89
130	Same, slim seed	21700	19096	2604	91
131	Up-to-Date—Carbondale	29464	.....	....	93
132	Peerless—1 yr. G.	29400	.....	....	86
134	Pearl—Valley P.	38000	35340	2660	..
133	G. Coin—Carbondale	30900	28737	2163	100
136	Pearl—Carbondale	32500	28925	3575	95
135	Pearl—Wisconsin	30100	26789	3311	91
137	Pearl—1 yr. G. sod	33200	28884	4316	98
138	Pearl—Del Norte	29900	26312	3588	97
139	Pearl—mixed, planted 2x11	32592	.....	....	..
	Same, planted 3x11	30400	.....	....	..
140	Peachblow—Ault	36300	.....	....	97
141	Peachblow—Carbondale	35700	.....	....	98
	Duplicate	37500	.....	....	..
142	Peachblow—Flagler	37800	.....	....	90
143	Peachblow—Greeley	30600	.....	....	89
144	W. Peachblow—G.	28000	.....	....	94

* Estimated at 11%, following test of 12% on slimmer stock.

PEACHBLOW CULLS AND CRAX

The per cents of smalls, crax and extreme slims were taken on the three highest yielding Peachblows. ("Crax" is the trade name for cracked potatoes).

Stake	% Smalls	% Crax & Slims	% Ware	Yield Ware
140	8	23*	69	25047
141	7	16	77	28875
142	8	26†	66	24948

* A large per cent. here of slims.
† Almost all crax.

PARSHALL 1910

Our Plot in Middle Park on the Moffat road was a sandy brown mesa loam several feet deep, with lighter colored and heavier subsoil on cobblestone drainage, an excellent potato soil. This was the third crop from sage brush, the previous ones having been grain and turnips. Conditions were very fine when planted on May 6 and 7. The plot did not receive water early enough, and was late when the freeze came on August 25, which destroyed $1,000,000 worth of potatoes elsewhere, and was

the record early freeze at the Experiment Station. Potatoes must have rotation with clover, alfalfa, or peas; and Middle Park is no exception; and such rotation regularly practiced will bring amazing results with all crops grown. This region, espectially with a James Peak tunnel, will be the closest mountain potato section to the Denver markets. Early potatoes can be ready at 8,000 feet by September 1. In 1909, our yields of Pearls—a medium late sort—were about 12,000 pounds per acre, on sage brush land at this point.

The Seed Grown on Sage Brush Land, at high altitudes, if watered early, we find good seed for the Greeley district. See Montrose, Greeley, and Julesburg.

The Pearl—first year Greeley or dry land seed—is the best main-crop potato for the Park. Rurals might be better on the heavier soils but are pretty late in maturing. For earlies the Cobbler and the Ohio are the ones to plant.

YIELDS AT PARSHALL

Planted 15x38.

Stake	Variety and Source	Total	Stand
108	Pearl—6 yr. Greeley	3168	95
106	Pearl—2 yr. Del Norte	5040	88
116	Pearl—1 yr. Parshall	5760	93
104	Pearl—1 yr. Greeley	5904	88
120	Pearl—1 yr. G. Sod	5616	95
105	Pearl—2 yr. Greeley	5184	94
107	Pearl—3 yr. Greeley	6048	95
119	Peachblow—Flagler	6348	89
110	Downing—Carbondale	3816	72
102	Challenge—Greeley	5184	88
101	Snowflake—Greeley	3024	70
115	F. Snowflake—Maine	6984	86
109	R. Seedling—Stove P.	3096	48
113	E. Ohio—Red River	2664	94
112	Six Weeks—Maine	2736	95
111	Cobbler—Maine	2160	75
103	W. Ohio—2 yr. G.	1584	95
114	N. Beauty—Maine	1018	70
117	E. Rose—Parshall	3876	74

JULESBURG 1910

Our plot here was an old alfalfa field, a gray loam, deep, with heavy but porous subsoil. It was irrigated early, plowed 8 inches deep, harrowed, leveled, rained upon and harrowed before planting on May 4. There are few soils better than this type at Julesburg. The reservoir of the Julesburg Irrigation District broke its dam early in the season, and the potatoes were never irrigated, while the rainfall was below normal. The potatoes were harrowed before and after they came up, and this was of great benefit. Potatoes intended to be harrowed should be planted deep, so as not to be harrowed out.

Boxing is a British title applied to potatoes sprouted in crates and set out by hand. Quicker growth and better yields are claimed for the practice. The early season was dry and unfavorable for this test. Our conclusions here, at Greeley, and Montrose are that better results are obtained by the use of stubby, sprouted, just started, or greened seed potatoes, in planters.

Wisconsin Seed tested here proved to be 78% Pearls and 22% mixed Rurals and other sorts. Such mixtures are not tolerated in established Colorado potato regions.

Dryland Possibilities.—The most significant result of the work in 1910 at Julesburg and one of the most important facts in Colorado agriculture, was brought out because the reservoir broke, and the plot became a dry land experiment. The yields of 10,000 pounds per acre on the

standard sorts is proof of what can be done on loamy lands with good subsoil, without irrigation, if properly rotated with alfalfa, beans and peas.

Dryland Rotations.—If peas are used they should be planted in the earliest spring time in rows for cultivation and on packed fall plowing or summer tilled stubble. Two years of peas are recommended, the first season cutting for hay, and the second plowing under the crop and summer tilling for potatoes to follow in the third and fourth years, returning to grain for the fifth year and then repeating. By this means all dry land crops will be vastly increased, and the irrigated potato regions greatly benefited by an adequate seed supply. The irrigation given the Julesburg soil before plowing we do not consider superior to summer tilling.

Varieties and Seed Sources.—We have much evidence here as elsewhere that those regions which buy Greely seed should buy if possible first year seed, and this is of added importance if the stock is again to be used for seed. The excellence of the sage brush mountain seed from Parshall and Montrose and the Cobblers from Mancos is affirmed in the yield of Rural, Pearl and Cobblers, and the desirability of dry landers' planting both early and late sorts is again illustrated. The Cobblers did fine and were beauties. We can only wish them equal in table quality to the Ohio. We do not favor for Julesburg any varieties but Rural, Pearl, Cobbler, and Ohio. We believe that this region with good knowledge of type and varieties and the facts of Bulletin 176 can maintain its seed stocks somewhat longer on its deep lands than can the Greeley district.

COOPERATIVE DRY LAND TESTS AT JULESBURG

Four Tableland Farm families* cooperated with us in tests of varieties for dryland growing, and gave most hearty and much appreciated

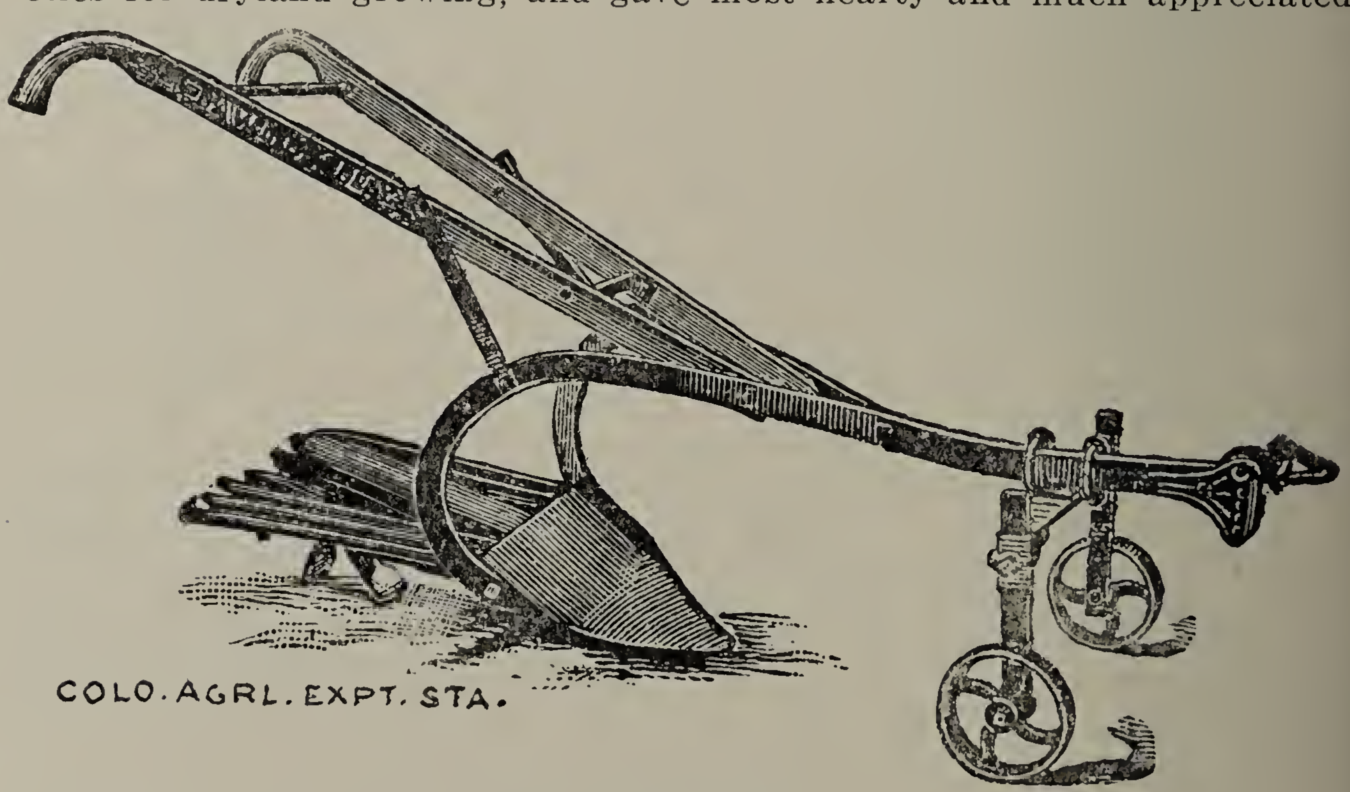

PLATE XXIII.

The Doublebeam Shaker Digger Handles Early Potatoes and Ripe Vines Very Well, and is Much Better than a Plow. Cost, $10.50 Chicago; $12.50, Denver.

aid in this work. On land carefully cultivated but not summer tilled or falled plowed in any case nor that had grown peas, beans or alfalfa, it was proven in this bad season, that dry landers can grow as a minimum 50 or 60 bushels or even more of potatoes. This year Pearls did by far

*We say "families," rather than "farmers," because the women and young folks in the tableland farm homes take their full share of work and interest in these things.

the best, as the moisture came late. Other years, especially with summer tilled land, early sorts like the Ohio will do better. Thus it pays to plant both early and late sorts to hit the season at one end or the other.

Summer Tilling and better early conditions will make better shape and better seed as well as increased yield. See under **Dry Land Potato Growing**, and **Julesburg 1910.**

YIELDS ON THE STATION PLOTS AT JULESBURG

Planted 14x38.

Stake	Variety and Source	Total	Ware	Culls	Stand
22	E. Ohio—boxed	10400	6200	4200	..
25	Triumph—boxed	7360	3840	3520	..
23	W. Ohio—boxed	5409	2254	3155	..
27	Cobbler—8 in.	12831	8554	4277	..
24	Cobbler—8 in.	10692	7026	3666	..
28	Cobbler—8 in.	10450	8250	2200	..
30	Perfection—8 in.	8250	5500	2750	..
3	Cobbler—Mancos	11100	9200	1900	..
4	Perfection—Maine	5600	4500	1100	..
1	N. Beauty—Maine	7900	6300	1600	..
2	Cobbler—Maine	11200	9600	1600	..
14	Pearl—3rd. yr. G.	9700	8300	1400	77
6	Ohio—Red River	9000	6500	2500	..
5	Ohio—2nd. yr. J.	10100	8000	2100	..
26	Pearl—boxed	6700	5600	1100	..
13	Pearl—2nd. yr. G.	9100	7200	1900	..
31	Pearl—2nd. yr. J.	9900	8400	1500	86
17	Pearl—Parshall	11300	9900	1400	67
19	Rural—Montrose	13100	11300	1800	84
12	Pearl—1st. yr. G.	11700	10200	1500	..
16	Pearl—Montrose	10100	8600	1500	81
15	Pearl—Stove P.	10000	8700	1300	70
18	Rural—1st. yr. G.	10800	9200	1600	80
20	Rural—Wisconsin	9800	8500	1300	..
9	Peachblow—Flagler	8700	6400	2300	..
10	Peachblow—8,000 ft.	8100	6100	2000	..
11	Peachblow—Carbondale	8700	6800	1900	..
7	Peachblow—Julesburg	7200	5900	1300	..
8	Peachblow—Greeley	8000	6400	1600	..

FORT MORGAN.

On June 9 we planted one acre at Fort Morgan with about 1/20 acre, one row, each of the following as a test of sources of seed potatoes of standard varieties for Fort Morgan:

Rural—Seed from four sources.

Pearl—Seed from ten sources.

Other Varieties—Three.

Grasshoppers practically destroyed the field. None of us realized how serious this pest would be here in 1910, or a long narrow field between grain and alfalfa would not have been chosen. A right good fight was put up when we realized the situation, but we could not have won unless we had had the special sprayer and arrangements used at Greeley.

Greeley Rules.—These will apply here, as to change of seed, deep cultivation, late planting, late watering, rapid harvest, as set forth elsewhere in this bulletin. In the vicinity of Brush heavy yields were secured, of excellent quality, both of Rurals and Pearls.

Varieties for Morgan County will be the Rural, Pearl, Ohio, and Cobbler. First year Greeley seed will do well, as will dry land seed which shows no signs of running out. Sage brush land potatoes from the mountains will do well, as will Wisconsin seed.

Morgan County dryland potato growers will find their problems discussed elsewhere herein.

GREELEY NOTES

All Yields at Greeley, especially of early potatoes were greatly reduced by serious shortage of water and holding it off too long early in the season. Water was so high in price that we could not require the rental of water extra to that normally sufficient.

The Largest Yields, in the order named were secured with Carmen

GREELEY YIELDS
Planted 15x38.

Stake	Variety and Source	Total	Ware	Culls	Stand
321	Rural—Divide, return	9810	7630	2180	72
322	Epicure—England	6750	5250	1500	80
323	Carmen I—Aroostook	16974	15744	1230	74
324	Pearl—Divide, return	13755	12838	917	..
325	Peachblow—8,000 ft.	10800	8800	2000	60
327	Carmen I—Penn.	11305	9282	2023	82
326	Abundance—England	10115	7735	2380	75
336	People—Carb.	10200	9400	800	83
337	Carmen III—1st. yr. G.	7000	5500	1500	87
338	People—Montrose	9500	8500	1000	70
339	Peachblow—Flagler	12400	10000	2400	77
341	Peachblow—Carb.	11900	9900	2000	75
340	Downing—Carb.	5500	3700	1800	88
330	Old's No. 116—Ohio	10920	9360	1560	90
334	Ninety-fold—England	7739	6540	1199	70
333	Banner—Red River	12102	10810	1292	90
328	B. Crawford—Ohio	13180	11680	1200	82
278	Pearl—1st. yr. G.	6700	4800	1900	..
348	Russet—Carb.	11900	10200	1700	92
349	Rural—Montrose	9300	8600	700	85
350	Rural—Del N. (big)	4200	3800	400	29
351	Rural—1st. yr. G.	6300	5700	600	81
331	Peachblow—Ohio	8000	6500	1500	82
332	Up to Date—Vermont	10865	9840	1025	66
335	Snowflake—Aroostook	9064	8038	1028	84
342	Pearl—Divide	13500	12200	1300	96
343	Pearl—S. P. (L)	9400	7900	1500	92
344	Pearl—Grover (N)	12800	11300	1500	90
345	Pearl—Grover (S)	14800	13300	1500	97
352	Snowflake—Stove P.	7000	6000	1000	45
353	Pearl—1st. yr. G. sod	12500	10700	1800	93
354	Carmen III—Plateau V.	10100	9300	800	86
346	People's—1st. yr. G.	7500	5700	1800	88
347	G. Mt.—1st. yr. G.	11600	9500	2100	97
355	Carmen III—P. V.	10000	9300	700	..
357	Carmen III—Wis.	15500	14000	1500	95
356	Carmen I—	11600	10600	1000	80
358	Pearl—1st. yr. G. (S)	12100	11000	1100	88
359	Prolific—Pagosa	13300	12400	900	75
360	Pearl—Montrose, G.	12000	10400	1600	97
361	Dewdrop—Maine	12100	11300	800	76
364	Pearl—S. P. (S)	10800	9800	1000	64
363	People—2nd. yr. G.	11800	10700	1100	86
362	Pearl—1st. yr. G. (D)	14300	12700	1600	89
365	Pearl—Limon (N)	16900	15100	1800	91
369	Pearl—S. P. (L)	14300	13400	900	74
370	Pearl—S. P. (L)	9400	8400	1000	48
371	Pearl—4 yr. Montrose	11900	10700	1200	85
372	Pearl—Wisconsin	13900	13100	800	68
	Same	14200	13000	1200	..
	Same	12800	11900	900	..
373	Pearl—S. P. (L, 8)	11600	10500	1100	..
	Same, 8.	13000	11900	1100	..
374	Pearl—S. P. 3x15	14600	13300	1300	..
366	Pearl—Parshall (W)	10900	10300	600	71
367	Pearl—Parshall (C)	13500	12500	1000	71
368	Pearl—S. P. (R)	8500	7900	600	51
380	Rural—Eaton	....	....	....	85
379	Rural—1st. yr. G. sod	11100	10200	900	78
378	Peerless—1st. yr. G.	10600	7900	2700	68
377	Pearl—Foothills (N)	11600	10000	1600	85
376	Peerless—1st. yr. sod	7700	6100	1600	60
375	Pearl—S. P. small (L)	11000	10300	700	68

I from Aroostook; Pearls from Limon, Colorado; Carmen III from Wisconsin; Green Mountains from Wisconsin; Pearls from near Grover; and Stove Prairie Pearls planted with three times the regular number of seed pieces (3 in each spoke). The Carmen I and the Green Mountain are of a shape unsuitable to Greeley conditions. The significant point is that no first year seed is in the first seven lots this year.

Close Planting of one lot of Cobblers increased the yield one third as did a double row of the same lot, while close planting of a first year Cobbler resulted in the lowest Cobbler yield. Close planting of Stove Prairie Pearl seed resulted in good yields at a cost for seed that would

GREELEY YIELDS
Planted 15x38.

Stake	Variety and Source	Total	Ware	Culls	Stand
241	B. Victor—Kimball	14200	12500	1700	92
243	B. Victor—Plateau V.	10900	9700	1200	85
242	B. Victor—P. Valley	.....	.....	....	73
244	Noroton—Maine	3600	2700	900	80
246	R. Seedling—Carb.	11600	9900	1700	89
245	E. Rose—Haxtun	11000	9700	1300	87
247	E. Ohio—Parshall	6000	5300	700	84
248	R. Seedling—S. P. (V)	5900	5700	200	58
249	Cobbler—Maine	4100	3400	700	73
250	Cobbler—Scotts Bluff	4500	3800	700	89
254	Same—double row	6100	4500	1600	89
253	Cobbler—S. B. 2x15	6000	4400	1600	84
251	Cobbler—Mancos	6600	5200	1400	86
252	Cobbler—Red River	6000	4800	1200	69
256	Cobbler—1st. yr. G. 2x15	3100	2100	1000	79
255	W. Ohio—Pagosa	4200	2700	1500	93
257	W. Ohio—Red River	3100	1800	1300	94
258	W. Ohio—Red River	3900	3000	900	87
259	E. Rose—Red River	9500	7900	1600	80
260	Six Weeks—Red River	4600	3600	1000	96
261	Thorburn's Early—	7740	6192	1548	80
262	Noroton—Sapinero	2992	1936	1056	93
263	E. Ohio—Sapinero	6698	4334	2364	93
264	E. Roser—Red River	6600	5300	1300	..
265	Triumph—Red River	4580	2748	1832	75
266	Cobbler—Akron	3658	2714	944	..
271	Bovee—Aroostook	7544	5576	1968	88
267	Cobbler—Aroostook	3825	2390	1435	98
268	Sunlight—Aroostook	4182	2706	1476	90
269	Perfection—Aroostook	5973	4525	1448	95
270	Dewdrop—Aroostook	7800	5980	1820	90
272	Noroton—Aroostook	.....	.....	....	50
273	E. Ohio—Aroostook	5713	4334	1379	98
274	Six Weeks—Aroostook	5900	4800	1200	87
275	Burpee—Aroostook	2900	1900	1000	100
287	Peachblow—Greeley	9400	7200	2200	..
286	Triumph—Boxed	7786	6412	1374	..
289	Rural—Boxed	11700	10200	1500	..
292	W. Peachblow—Boxed	12513	9288	3225	..
291	Pearl—Boxed	8930	6000	2930	..
290	Rural—Boxed	8316	6264	2052	..
276	"Pearl"—Maine	8200	6500	1700	86
277	Pearl—Del N.	11800	10700	1100	85
280	Pearl—1st. yr.	11000	9400	1600	94
283	Carmen III—Plateau V.	11300	10300	1000	78
284	G. Coin—Wis.	9700	8400	1300	79
279	Pearl—Carb.	12600	11400	1200	91
281	Pearl—Montrose, G.	9400	8000	1400	93
282	Pearl—Pagosa, G.	12500	11000	1500	87
293	G. Mt.—Wis.	15300	14000	1300	..
294	G. Mt. Jr.—Wis.	14900	13600	1300	88
295	E. Ohio—Wis.	5500	4300	1200	91
296	Thorburn's Early—	14178	12638	1540	94
297	State of Maine—Wis.	12204	10735	1469	85
302	Pat's Choice—Wis.	8500	7500	1000	45
314	Downing—Montrose	9180	7140	2040	75
315	Rural No. 2—Wis.	13800	13000	800	94
316	Carmen I—Maine	12528	10692	1836	91
318	Taft—Ohio	5848	5440	408	..
319	Snowflake—Ohio	7837	6462	1375	71

often pay. See Del Norte and Carbondale notes on close planting.

Other Points that may be cited are the promise of the Russet as a secondary early, borne out on the other plots: that Pearls first year Greeley from Montrose sage brush lands did as well as any Pearls the first year from dry land. This seed we have tried out for three years with the same result.

Changes of Pearl Seed.—All lots taken to the Divide, to Pagosa, to the plains, to the foothills, to Stove Prairie, when returned have this season done better than local seed. There is no exception save the one where run-out Greeley Pearls went to Montrose and returned. We find elsewhere that the tendency to run out may be held in check so far as yield is concerned, by changes, but will return at once, or after a season, with ruinous results when the seed is brought back to the old conditions, as often occurs with irrigated sod seed, at Greeley.

Stove Prairie seed continues to give good type and good yield per plant but very poor stands. We have shown that it paid **this season** to plant this seed thick in the row. Many tubers of seed size make up a good yield, although they appear small. We brought down in November 1909 several lots of Stove Prairie Pearls and had them carefully stored at Greeley. The stands were improved by this careful storage only five or ten per cent. During the winter of 1910 and 1911 we are securing Stove Prairie seed of different history to be tried in soils on hand from Fort Collins, Greeley, Del Norte, and Stove Prairie. Professor Sackett, our pathologist, has twice visited Stove Prairie with us to try to find some clue as to the cause of this rot. We regard this as one of the most important and most puzzling problems we have on hand.

SPRAYING FOR GRASSHOPPERS AND FLEA BEETLES

Bordeaux Mixture* applied with a twelve nozzle four row sprayer which covered the whole plant was used by Mr. Atkinson five times on the whole plot of four acres, and on the Atkinson, Badger and Emerson farms, to test the great value of Bordeaux as a repellant to grasshoppers and flea beetles, as reported in Vermont and on Long Island. See **Potato Insects** herein.

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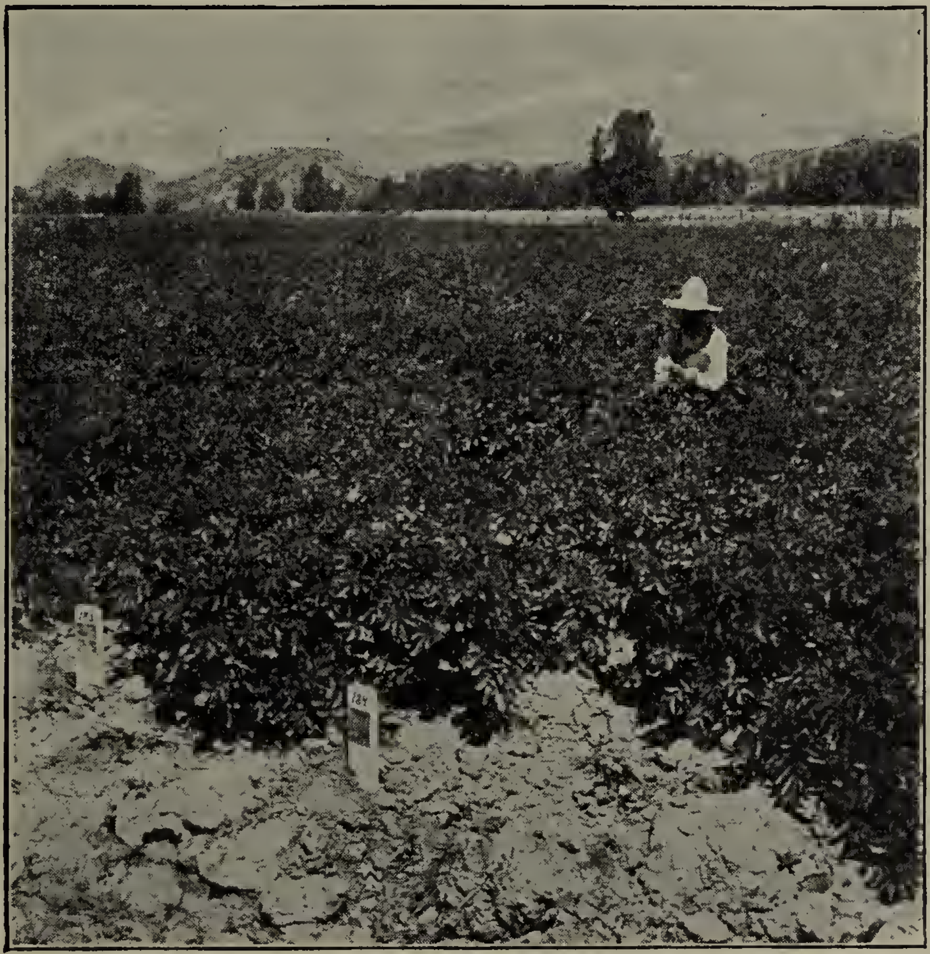
*Potato growers will find our arrangements at the Greeley plots for preparing Bordeaux mixture very convenient. A platform is required some six inches higher than the top of the strainer used on top of the spraying machine, and the water supply should discharge quickly into barrels standing on this platform. Four barrels are required: Two called **dilution barrels**, with hose attached to empty them into the 100 gallon tank of the spraying machine; while two barrels are used for **stock mixtures**. In one, 50 pounds of blue stone or copper sulphate suspended in a sack is dissolved in water and made up to fifty gallons. In another lime is water slaked in like proportions, one pound to the gallon. A box strainer with a bottom of common wire netting is then set over the dilution barrels, and into one with a gallon dipper made of galvanized iron, five gallons of the stock copper sulphate solution is poured out and made up with water to fifty gallons. Into the other barrel, after stirring well the stock solution of lime, five gallons containing five pounds of lime are strained and made up to fifty gallons. At this point equal quantities of each solution are put into a wide mouthed bottle and after being mixed by shaking, the mixture is tested with a drop of potassium ferrocyanide solution made from ten cents' worth of the drug. If a brown color results, the mixture will burn the leaves, and more lime from the stock barrel must be added to the dilution barrel until the test no longer shows brown. Then the two dilution barrels are emptied simultaneously into the sprayer strainer, the hose being regulated as to height so that the barrels empty evenly. Common blue stone costing about seven cents per pound in barrel lots, and the best of stone lime are used. Freshly slaked lime or that carefully covered with water and otherwise kept from the air is required. In some places lime contains magnesium impurities which are of no use in Bordeaux mixture.

Bulletin 176. November, 1910

The Agricultural Experiment Station OF THE Colorado Agricultural College

Productiveness and Degeneracy of the Irish Potato

Preliminary Studies Mostly Within the Pearl Variety



HYBRIDIZING

BY

C. L. FITCH

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1910

PLATE VI A FINE FIELD AT GREELEY.
An Intermediate Vine.

A PEARL TUBER: Part aerial, part underground.
A BLUE VICTOR "BASTARD" VINE: One plant between No. 4 and No. 5. Blossoms but no seed balls.

PRODUCTIVENESS AND DEGENERACY OF THE IRISH POTATO.*

Preliminary Studies mostly within the Pearl Variety.

By C. L. Fitch, Potato Specialist.

There is every reason to believe that principles true of one variety will be fundamental to all varieties of Irish potatoes. We submit these observations, however, in their bearing upon one variety only.

Cause of Tuber Degeneracy.—We find that within the Pearl variety, tubers become deep eyed, knotty, long and unproductive because of conditions that make the whole plant tend toward going to seed. Attention is called to the tendency of the tubers, which are enlarged stems, to be controlled in shape by the general habit of the plant. We also trace the branch and leaf habits which parallel tuber productiveness and degeneracy, giving drawings of the typical character of vines and corresponding photographs of tubers and using aerial tubers as proofs that certain tuber parts correspond to certain portions of other potato stems.

Sexual Tendencies.—We find the indicated factors of the tendency towards bearing seed to be early dryness, close and deep cultivation, and disease. We find that tuber productiveness in Pearls is in-

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* The following is essential to the argument but not a part of it.

THE PEARL, PEOPLE'S, AND THE BLUE VICTOR, IDENTICAL EXCEPT IN COLOR.

The Pearl originated and still comes by bud variation from the Blue Victor. Of this family is the People's variety. All are alike in shape, excellent keeping quality of the tubers, quick sturdy growth, and medium time of ripening.

The vines and leaves, branching habit and tuber arrangement are alike in the three sorts, with the exception of the darker color of the whole Blue Victor plant, as might be expected from the tuber color.

The differences in the tubers of the three sorts consist in color and the character of the outer skin. The Blue Victor is of a purple color which, on exposure to the light, fades to a leaden brown, and is often streaked with white. This usually appears to be due to cracks in the skin, but sometimes appears to be the real outside color by variation, and when so covering an eye comes true in most cases both in the first propagation and in the succeeding crops of Pearls. The Pearl is brownish white with, at best, a well russeted skin, but there are often smooth spots on russeted Pearls, or whole crops that are nearly unrusseted. In the People's variety a deeper brown characterizes even the unrusseted skin of tubers, and both the russeted and the smooth skin appear to be thicker. On all the three sorts there are spots on occasional tubers, or more rarely whole tubers, which resemble and are identical with each of the others,—including blue spots or blue potatoes from both the Pearl and the People's. The color concentrated at the dormant sprout tips of the three sorts of tubers, at

versely proportionate to the sexual development of the plant; tha the most degenerate tuber is grown by the plant which carries full developed flowers and virile pollen; while those plants on which onl the female portions of the flowers appear to be fully developed pro duce tubers intermediate in form and yield, and that the best tuber and the largest yield are produced by the type of plant whose bud do not even swell.

Practical Bearings.—The way is opened to study out:

1. What conditions insure productive seed potatoes.
2. How to grow potatoes free from defects.
3. What are the best changes of seed potatoes, and why.
4. How best, if way there be, to grow Pearl seed potatoes without change.

Additional light may be secured thereby on all problems of plant production where the seed is not the desired end.

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occasional stem nodes, and which tints the underground part of the main stems, is alike in the three sorts,—deep in the Blue Victor, and faintly pink in the others.

We go minutely into the characteristics of these three sorts because it is essential to our reasoning that the varieties are **one**, with **three** sorts of color; while the corresponding degrees of tuber degeneracy occur in the three colors and therefore cannot be confounded with the chance introduction of tubers of other varieties.

Alike, among the three varieties, we find the same ideal types, the same average tubers, and the same degenerate forms. With tubers Nos. 4 and 5, Plate IV, there is a change to a lighter color—a phenomenon not yet understood. In the Blue Victor, the "bastard" form is lighter pink than the others; among Pearls, the bastards are whiter and more waxy in color, while in the People's variety, the bastard forms, when placed beside Pearl bastards show the deeper brown shade that is a characteristic difference betwen the varieties.

The term **bastard** is one employed by growers and is herein used to mean a certain degenerate form of tuber of the Pearl family.

Environment of Plants Observed.—The writer has had experimental plots at elevations of 3500, 4000, 4500, 4800, 6500, 7000, 7800,, and 8100 feet, and on soils ranging from light sand to clay loam, and with fertility varying from the limited nitrogen and humus content of lands never yet deeply moistened by nature and supporting only scant buffalo grass or scantier sage brush, to that of irrigated alfalfa lands perhaps unexcelled in natural fertility and nitrogen content. See Bulletin 175 of this station for a discussion of **The Potato Industry of Colorado.**

The Solution of a Leading Problem of one of the most highly specialized of farming communities is herein sought for the sake of that community and of the potato industry. The study is founded upon the previous work of the Station and is an out-growth of that spirit at Greeley which makes potatoes and the intricate problems of potato growing the leading topic wherever farmers get together, whether at the open meetings of the women's country clubs, or when neighbors talk over the fence in the field.

Other Names: Of the Pearl.—Peerless, White Victor, Valley Prize, Mammoth White Pearl, and, in the opinion of Sutton & Sons, the Puritan, of Great Britain. **Of the Peoples**—Polaris, People's Party.

Future Development Work.—The way is pointed to explanations of the indicated superiority of seed potatoes grown under mulch and of those dug as in England before they are ripe. The promise of the future is that conditions favor the production in the Rocky Mountain region of the new varieties of the future, because on the arid irrigated plains the plants may be made sexual at will, be crossed, and then be developed under ideal irrigation conditions in our mountains. Improvement in varieties, which normally have a greater sexual de-

PLATE II. AN IDEAL HILL OF PEARLS.
Without Compound Eyes, Deep Eyes or Knots.

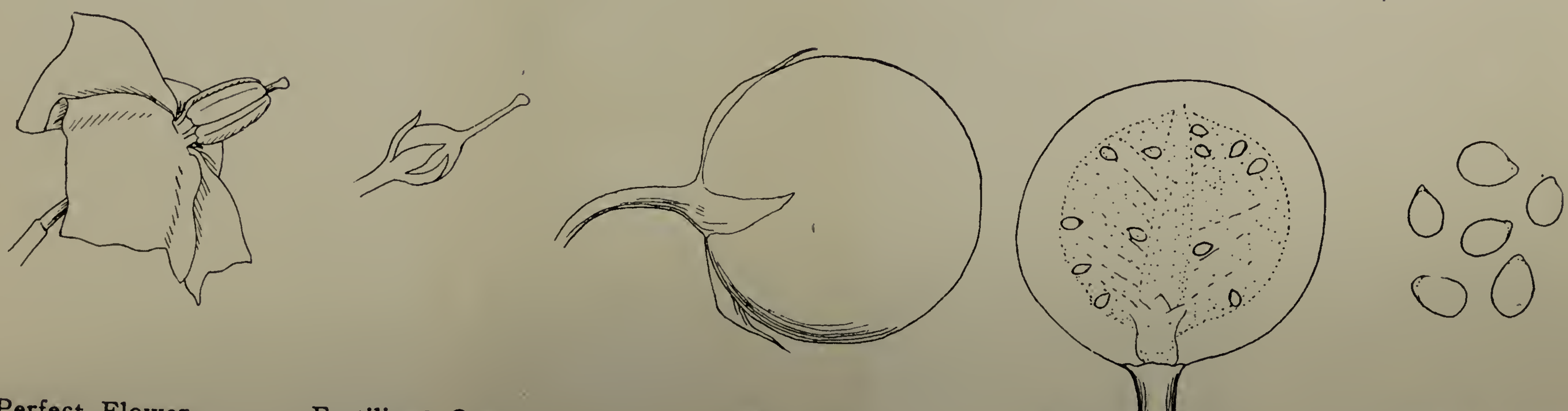
velopment than prolific Pearls, will doubtless be found in the selection of those plants and tubers which are the most completely asexual in habit.

AN OUTLINE OF THE OBSERVATIONS ON WHICH THE FOREGOING IS BASED.

The Pearl Potato and the Pearl Seed Supply.—The Pearl is medium in time of maturity, and is better adapted to most regions of Colorado than any other sort. It is a great surface feeder and is adapted to soils made shallow by underlying moisture or gravel. It is a good keeper, and its vines are little subject to attacks by *Fusarium,*

PEARL VINE DEGENERACY.

1.. Best Type 2. Common Type 3. Intermediate 4. "Bastard" 5. Seed-bearing Bastard



Perfect Flower Fertilized Ovary Seed Ball Vertical Section Seeds Magnified

PLATE III. PEARL BASTARD: SEED BEARING PARTS.
Drawings by Miriam A. Palmer.

or its tuber to dry rot. The quality is excellent under good conditions.

Those regions which find Pearls their best variety are unable to maintain Pearl yield or shape, and are compelled to buy seed from other regions every year for raising the seed tubers to plant the large fields for the following year. Greeley also finds the Pearl variety subject to knots. In fact the most pressing economic need for the potato industry of Colorado is the increase and betterment of the Pearl seed supply.

Pearl Vines, Tubers and Blossoms.—The most productive Pearl vine (No. 1, Plate III.) stands, not erect in any of its parts, nor yet prostrate, and is typical of good conditions and good yields of tubers, free from knots and from deep or compound eyes. Where subjected to early drouth and close deep cultivation (No. 2) and then given abundant moisture, the main stems grow longer and interfere with the running of water as they become prostrate from the weight of "risers" which grow straight up from the nodes. The tubers produced by this common type of vine, while usually good, have deeper eye pits

PLATE IV. COMMERCIAL PEARL SEED.

1. 2. 3. 4. 5.

Good — Fair — Intermediate — Pearl Shaped Bastard — Pear Shaped Bastard

and more bulging eyes, and are subject to knots. About September 1st good fields of No. 2 look like alfalfa fields, the growth is so rank and the surface of the field so even. Such a field is shown in the photograph, behind the irrigator, with a single No. 3 vine in front of the coat. Plate VI.,page 2.

This type (No. 3) marks the change from value to worthlessness. Fields that are rough and ragged over the top from the presence of No. 3 and No. 4 are undesirable as a source of seed. These vines are much alike, except that No. 3 divides the top. The blossom of No. 4 is more developed, and its tuber shows sudden and great degen-

eracy. Both No. 3 and No. 4 have been found only as single plants in the hill, which peculiarity may be attributed to strong tendency in the seed piece to grow single stalks and no side branches at the eye. No. 5 bears fertile pollen and large fruits with many vigorous seeds. It has more than one plant to the hill and loses the strong central character, but all the branches are erect, while the tuber becomes a pear shaped degenerate. There are of course forms intermediate between these types, but as a whole the steps are surprisingly distinct.

Pearl intermediates and bastards are found in the crop from the same seed which under better conditions produces only Nos. 1 and 2. For instance, a lot of Pearl seed, grading No. 2, from Del Norte, produced at Carbondale, in 1910, no intermediates or bastards, while the same lot of seed under the degenerating conditions of 1910 at Greeley produced many of both intermediates and bastards. We have found the same true with us time after time from seed sorted and restored, tuber by tuber by experts.

Sexual Tendencies Stronger than Selection in the Greeley district. The writer for four seasons, commencing with 1905, practiced near Greeley hill selection* of seed potatoes. In 1908 he selected from hand dug hills in the field a carload of seed Pearls and in 1906 a half carload. The tubers kept good in shape, even improved in outline, though the eyes were a little deep, and the reduced yields were ascribed to seasonal and other causes. The main stems became gradually stiffer. After the fall frosts the "first year" vines were prostrate, their leaves in the ditches, and the stems showed white as they lay on the hill, while the "pedigreed" vines had stiff upright center stalks which carried a brown flag of frosted leaves. The fields could thus be told apart to the row by their color as far as they could be seen. In 1909, on the same farm, because, it seems, the seed-bearing tendency had accumulated to override all other influences, the type and yield gave way to long cylindrical and irregular shapes with many bastards and seed balls. These Pearls in 1909 did very well at Pagosa and at Montrose and fairly well on the college plots, but, in 1910, from all these sources, on our various plots, and at Pagosa and Montrose, in private hands, showed their degeneracy of vine, tuber and yield. We have noted at Carbondale the gradual improvement of Pearls and other varieties long grown under ideal conditions, as compared with the type of Pearls more recently brought from places where they had approached the intermediate form.

Blossoming of Pearls.—Neither the Blue Victor, the Pearl, nor the People's when at its best blossoms at all. The buds form early on relatively obscure stalks, but do not swell, do not show any color besides green, and soon blast and break off. This is true of vine No. 1, and to a large extent of vine No. 2, which last is characteristic of the Greeley district. Vine No. 2 will sometimes show color in the buds before they fall, and adverse conditions may produce late buds of this sort on No. 1; while severe dry early conditions will incline the habit of No. 2 in August strongly toward that of No. 3, and late bloom will be

*See this subject in Bulletin No. 175.

profuse. The blossoms of No. 3 are usually abundant, and while the female parts appear to be well developed the stamens are incompletely developed, and do not bear pollen. No. 4 is like No. 3, but with greater sexual development and a marked approach of the tuber toward that of No. 5, which bears abundant large seed-balls, with many and vigorous seeds.

PLATE V. PEARL BLOSSOMS.
Drawing by Miriam A. Palmer.

Intermediate Forms have a greenish yellow stamen, sometimes replaced by a hair, and always lacking in shape, color and pollen. No. 3 vine.

No. 5 Vine bears fertile blossoms with full corollas and orange colored stamens, with abundant virile pollen.

Conditions at Greeley.—The soil in this region, when well rotated with alfalfa, and especially when manured for a series of rotations, is exceedingly fertile, so that there are farms on which for years a yield of forty bushels of wheat per acre has been the minimum and where sixty bushels has been exceeded. As in most of the upper plains regions, there is a large element of adobe or gummy clay present in the major part of the soils of this district; and even when a part of sandy friable loams, this gummy ingredient is an adverse factor in the growing of potatoes, especially under irrigation on lands rather too flat* for water to run without puddling the sides of potato hills. Thus, with conditions favoring soil diseases of the potato, it has been proven by long experience at Greeley that on the average farm very close and very deep cultivation is the most profitable. The region and its people co-operate well and this system when once worked out has been applied to all lands alike, even where greater slope and more open soil make so rigid a system less desirable.

*See in Bulletin 175, Irrigation, Potato Diseases and Cultivation.

To make the best use of water and to delay air exclusion, if possible until the cooler weather of late July and August, irrigation is put off until the plants show considerable signs of suffering for water, or until in most cases after the first blossoms have opened and the tubers set. In most seasons there is moisture about the lower roots sufficient to sustain the plants, but as no rains come, there is not moisture enough above the seed piece, and no tubers are set until well into August, because tuber stems do not start unless moisture is in actual contact with the main stems. This is the chief reason for hilling potatoes—to more thoroughly mulch the soil about the main stems, and is said to have been discovered in Germany in the early days of potato culture there. It is one of the basic principles of potato growing.

Thus in the Greeley system the deep close cultivation tears off side roots, dries out the soil, and reduces the food supply at and prior to blossoming time. A well known scientific law which applies both to animals and as here to plants has been formulated by Doctor J. C. Arthur of Purdue University as follows: "A decrease of nutrition during the period of growth of an organism favors the development of the reproductive parts at the expense of the vegetative parts." With this fact all the farmers are familiar in its application to farm animals, and, in Colorado, growers of wheat and of alfalfa for seed production know that the withholding of water at a certain stage of growth increases the set of seed.

Associated at Greeley with methods that reduce the supply of available food at the budding and blossoming season, we have an unnatural delay of tuber formation, and the use of food therefore, followed, when irrigation at last commences, by the instant availability of a large food supply. Thus we have all the requisites for variation* of the plant in all its parts at the time of tuber growth in the direction of any impulse given it by previous conditions. Disease is also a large factor, often the largest factor, in potato plants tending toward going to seed. Often when the underground stems and tuber stems are attacked, especially in rich conditions, by fungous disease, there is induced a trouble called in Colorado "Little Potatoes." The prominent symptoms of this disease are the growth of large vines and many and large side branches, and the formation above or just below the ground of many small knotty tubers. These side branches blossom profusely, even when grown from tubers borne by prolific non-blossoming plants, but do not appear, the first season, to bear pollen.

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*Abundant food supply is recognized by plant breeders as promoting or allowing variation, reversion, or "sporting;" and wild plants are considered to be more stable and uniform in their characteristics because struggling in nature with other plants for food, they are less richly nourished than when cultivated by man and thus favored, protected and allowed to develop freely their inherent qualities.

Professor Alvin Keyser cites the work of Professor E. G. Montgomery, which affords a somewhat parallel phenomenon with Indian corn. About fourteen nodes are typical of the corn stalk, the upper seven of which are long and may develop tassels or male flowers, while the lower seven have power to develop female flowers and ears of corn. Normally one or two ears are formed and at upper nodes of the lower seven, but in the case of accident or removal of the ears naturally developing, ears may be formed at other nodes, and experimentally it has been found possible to induce the development of ears at all of the nodes.

The Influence of Nitrogen.—"Speaking generally, excessive food supply leads to infertility among both plants and animals. The former vegetate luxuriantly, but they do not blossom and fruit so abundantly as under a full but moderate supply of plant food." We were justified in making the assertion "that extreme proportions of nitrogen produce luxuriance in stem and leaf at the expense of flower and fruit."* Potatoes need rich conditions to continue productive vegetative growth. Experimentally and in commercial practice we find that seed potatoes grown from good stock and under good early conditions of moisture and health, but with only a moderate amount of plant food, on our buffalo sod or sage brush ground,† expand into remarkabe vegetative and tuber growth when planted on our rich alfalfa lands, are most nearly asexual in habit, and have the finest tubers the first year, with usually the largest production the second season.

Change of Soil.—Change from one region to another, or from one farm to a different but not richer soil, affords a change of food which is also a stimulus to potatoes and retards sexual development, thus maintaining to a degree good tuber shape. We find, however, that constant change may hold in suspension for several years the tendency to seed bearing and tuber degeneracy, which may then come suddenly, on return to less favorable conditions, or on being grown for a second year on the same ground.

Identity of Tuber Parts.—Aerial tubers give the best proof of the morphology of tuber parts. Plate VII is a Pearl plant from which the tubers were removed by hand in 1910 at Del Norte. In this case the plant not only enlarged upper branches, many of which formed into tubers, but also enlarged the main stem with normal potato-tuber tissue. In Plate VI, page 2, note a Pearl tuber also from Del Norte in 1910, the result of disease. One portion of the tuber was grown above ground and one below. These tubers show that the eye yoke is the laying of the leaf onto the stem; that the yoke point is the remnant of the leaf stalk base; that the sprout tips are the ends of leaves later to be followed by the sprouts; that knots are swelled, protruding branches of tubers; and that "compound" eyes are but lesser knots. The emphasis of the yoke on aerial tubers is quite like the dif-

* E. Davenport in Principles of Breeding, 1907, page 226.

† To a less degree this is true of seed potatoes grown upon pea stubble.

ference of main stems below the ground and above. Below ground the stems are smooth, while above ground potato stems are squared by successive leaves whose bases spring from the stem. In Pearl bastard seedlings, which are strongly sexual, the stems are squared—even winged by the leaf stems.

PLATE VII.
Pearl Aerial and Main Stem Tubers.
The result of removing natural tubers.

Color and Degeneracy.—With the old Peachblow, and with Pat's Choice and other varieties, the pink color follows the yoke lines, and strong color seems associated with sexual or degenerate tubers. With Ohios and improved Peachblows, the better the conditions the lighter the color of the tuber, and the worse the conditions and the type, the deeper the red color, the heavier the yokes and the deeper the eye pits or the more protruding the eyes. With Ohios, knots and seed ends are often of color diverse from that of the main tuber, or of other knots, possibly from varying influences during growth. Similarly, we often note different types on the same tuber, and we have a photograph of a Cobbler tuber, which is long, and in three sections—the first round, the second elongated, and the third a true Cobbler again. Peachblow tubers often project the main stem forward with all the end eyes and form either a new tuber or an end knot, usually of a darker red color.

HYBRIDIZING.

The Pearl is one of our healthiest varieties, is medium early and a heavy cropper. If in a large selection of hybrids with the Rural we could find one plant which retained the desirable qualities of the Pearl with somewhat more of the balance and smoothness of the Rural tuber, the value to the Colorado industry would be great. At Del Norte, in 1910, Francis Chisholm made sixty-seven crosses both ways between the two varieties. Twenty-five seed balls were secured but a hail storm

reduced the number to seven. One of these was of Rural pollen on Pearl and contained no seeds. The six of Pearl pollen onto Rural all bore abundant seeds. We judge incomplete fertilization characteristic in Colorado of Rural pollen and of the pollen from the Early Rose family as we cut open 650 seed balls of these sorts and found no seeds.

Next to the improvement of the Pearl, the most important work of this kind in Colorado is the introduction of some more disease resistent factor into both vines and tubers of the Rural family, and this result may be obtained in connection with the improvement of the Pearl.

A third object is the securing of a better early variety than the Ohio or the Cobbler. If the desirable qualities of these two varieties can be combined, the benefit will be very great to all who grow or who eat potatoes.

Our experience indicates that the crossing of varieties can be done with the best success at Greeley and Del Norte, and that selection and development is likely to be most successful at Carbondale. We find also that the best conditions for final seed potato production are likely to be those of the dry regions of Northeastern Colorado or of the Arkansas divide, and of high sage brush lands under ditch.

It is calculated that if Pearls can be made to run smooth and not knotty, and Rurals made more healthy and a little earlier, that the Colorado crop will average to be worth at least five per cent. more money. Such improvements should be accompanied by at least an equal gain in yield, as herein foreshadowed, so that we may expect such work if eventually successful to increase the returns from potato growing at least ten per cent. in Colorado. This percentage on our crop is already $600,000 per year.

BALANCE: A NEW TERM DEFINED.

Balance may be here defined as the proper relative growth of the main stem, branches, and leaves and the proper relative influence indicated by aerial tubers to be exercised by each upon the shape of tubers formed by the swelling of underground stems. Eyes are shallow when the leaves and branches are in balance each with the other, and affect the surface of the potato equally. With such potato vines as have strongly sexual main stems tending to become seed stalks, the branches of the main stem are relatively weak and short while the leaves and the leaf stalks are very strong so that the main stem is crooked and takes an altered direction from every point of division from the leaf stalks. In the tubers borne by such plants, the leaf yokes are very prominent and the bottom of the eyes, which are the tips of the branches or sprouts, are receding, thus forming deep eyes. In such tubers in most cases the number of branches and the number of leaves includeed within the tuber are increased so that the tuber is relatively long with many and deep eyes. The formation of such tubers from stems whose counterparts above ground bear many short branches and many stiff

leaf stalks growing from a stem of elongated character may be conceived to account for such tubers being circular rather than elliptical in cross section. The better the balance of tubers the flatter they are and the more run out the more nearly circular their cross sections.

Strong side branches and the tendency of branches to turn upward appear to be coordinated with tubers being flattened, as are all our sorts to some degree when most productive, and with the fact that most of the eyes of such tubers are on the upper side. When first formed, such tubers are not flattened, the Rural for instance being, when newly formed, circular in cross section, and later flattened.*

Aside from the above stated element of proper balance in potato plants, there is another element of balance, the tendency of stems either to stop growth before the tuber growth ceases, or to go ahead of the growth of tuber parts and tissue. The improved Peachblow potato is perhaps the best example of this. It has in many cases a recessed seed end, and in many cases it renews growth from this end, forming, especially with seedlings, which are more sexual, a series or even a "necklace" of tubers on one stem. In this variety also there is a noticeable tendency for growth to start from within the tuber, possibly from dormant buds. Large tubers of this variety crack very seriously and within the cracks are found what appear to be internal tubers or knots bearing eyes like those on the exterior surface of the original tuber. When flattened, large Peachblows seldom crack.

The element of balance shows in Pearls in another way namely that tuber stems of more strongly sexual plants are more subject to the tendency of the branches to grow and form knots. Growers commonly say that uneven watering occasions knots, and they are undoubtedly right, except that the tendency of previous years is perhaps a more important factor.

HARMONY OF PLANS FOR POTATO BETTERMENT.

It is a great satisfaction to feel the entire harmony of objects sought in potato breeding. Within the bounds of a variety the largest yields, the most desirable flattened tubers, and the shallowest eyes, go together. Conditions that favor one of these qualities favor the others. The largest profits to growers, and best quality for the housekeeper come from the same fields. Undesirable cylindrical shape, undue length of tuber, bulging or "compound" eyes, knots, deep eyes, and irregular shape, altho affected by varietal differences, appear to have common causes and common remedies.

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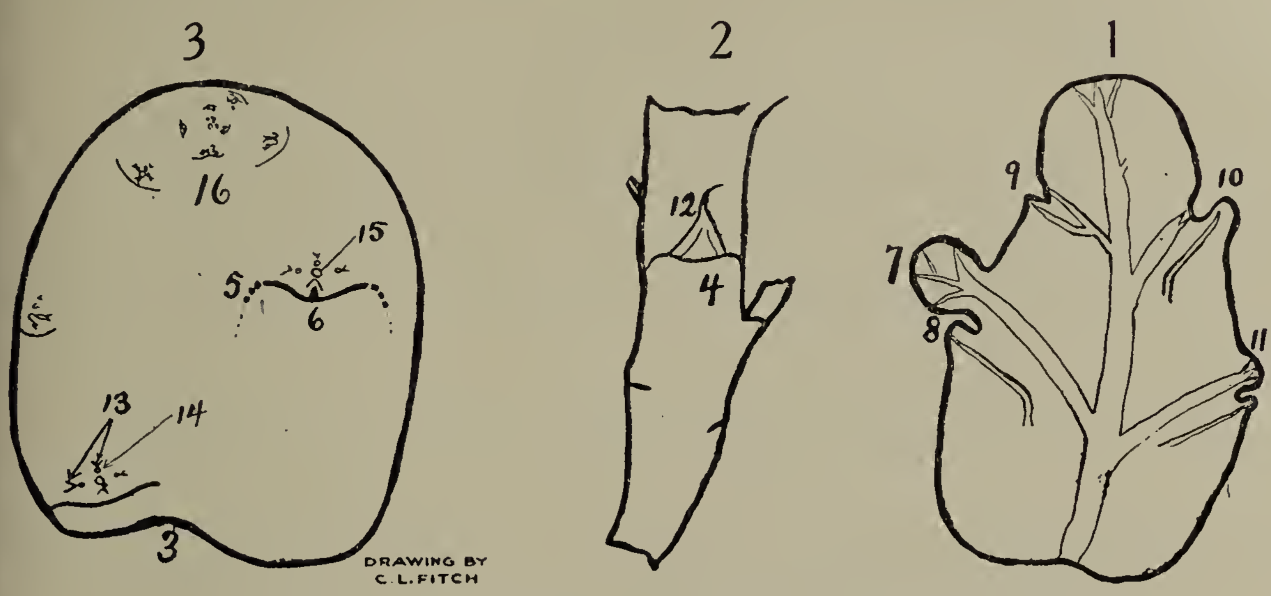
*Flattened seed tubers, other things being equal, may be expected to be most productive. We have noted this with Snowflakes and have found the Russet to be quick to respond to selection of wide seed tubers. At Carbondale, in 1910, we obtained from wide seed Russets 6,257 pounds per acre more than from slender round tubers of the same stock.

TUBER PARTS NAMED.

This plate is prepared to make clear the definitions herein given of tuber parts and defects. The plate is numbered from 1 to 16, as below explained.



TUBER NOMENCLATURE; PLATE VIII.

1. Longitudinal section of a tuber with defects.
2. A portion of the main stem of a potato plant.
3. A Pearl tuber with *recessed stem end.*
4. *Leaf Yoke* or line of separation of the leaf from the stem and corresponding to the eye yoke at No. 5.
5. *The Eye Yoke* on a good tuber has only the central portion On degenerate tubers, it is stronger, and on aerial tubers runs down at the ends as indicated by the dotted line at 5.
6. *The Yoke Point* is absent on the best tubers but is strong on the sexual tuber shown on Plate VI, page 2. No. 6 corresponds to No. 12, the stub of the leaf stalk.
7. *A Knot* or protruding tubered branch, accompanied by a deep eye pit.
8. The *eye pit* is here deep.
9. A deep eye *pit* without a knot.
10. A heavy *eye brow* and a deep eye pit.
11. A *compound eye* and a deep eye pit.
12. The *stub* of a leaf stalk, corresponds to No. 6, the *yoke point.*
13. *Eye blinds* are little bracts just *outside* the sprout tips.
14. A *side sprout* tip.
15. A *main sprout* tip.
16. The group of eyes here suggests the growers' name, *seed end.*

GOOD PEARL SEED POTATOES: TEN RULES.

Founded upon the foregoing or explained thereby.

PEARL SEED IS BEST TO BE:

1. From a field free from bloom and the ragged appearance produced by the presence of many vines of types Nos. 3 and 4
2. Of true Pearl shape without yoke points or deep eye pits, and with the fewest possible knots and compound eyes.
3. From dry land sod or high altitude irrigated sage brush lands with plenty of slope.
4. Brought from less to more fertile lands—not the reverse.
5. Exchanged between farms of the same region, rather than kept on the same farm.
6. Not from land where, if soil diseases are a factor, the crop was grown after potatoes.
7. From fields watered early, where slope and temperature allow this to be done without causing disease.
8. If from above the ditch, from summer fallowed lands planted rather deeply.
9. From fields which produced a good yield of medium sized tubers, and did not run too large, because in the latter case the tubers of seed size are apt to come from the weaker hills.
10. From special seed patches planted close, and perhaps dug early.

CHANGE OF PLACE OR SOIL is not the whole problem.
THE TYPE OF THE TUBER does not answer all our questions.
AT LEAST THREE YEARS HISTORY of the stock is necessary.

Bulletin 177. June. 1911

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

HOLD-OVER BLIGHT IN THE PEAR

BY

WALTER G. SACKETT

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1911

HOLD-OVER BLIGHT IN THE PEAR

BY WALTER G. SACKETT

There seems to be some difference of opinion among the fruit growers in this state as to whether the microorganisms which produce fire blight in the pear, apple, quince and apricot can live through the winter in the diseased limbs, twigs and fruit of the previous season under Colorado conditions and still retain their virulence in a degree sufficient to start off a new attack in the spring. Practically all agree that the hold-over form of the malady exists in the old cankers of the trunks, such as are found in the Ben Davis tree, and most of them are familiar with the characteristic oozing of the sticky gummy material in the spring, but the disagreement which has arisen has been concerning its persistence in the smaller limbs and twigs.

On the one hand, if the germs can survive the cold weather and the drying, then there is the greatest necessity for thorough inspection and careful removal and destruction of every infected portion of the tree before any new growth begins; on the other hand, if the causal organisms are destroyed by natural agents, there could be a big saving of labor at the time of the year when the orchardist's services are in demand for the routine pruning. He would not feel the urgent need of cutting out the blighted wood before doing anything else, and could postpone this to a more opportune time. Furthermore, the usual precautions to disinfect the tools and freshly cut surfaces, when working in blighted material, would be unnecessary, and there would be no objection to removing the diseased limbs while the general pruning was being done, so far as spreading the contagion is concerned.

It is not at all uncommon to find in the literature on this subject such statements as the following: "the germs gradually die, due to drying out of the canker so that at the beginning of the dormant season *very few** such cases show live germs present;" "The key to the whole situation is found in those cases of active blight *(comparatively few)* which hold over"; "These *few* cankers in which the bacteria survive the winter are called 'hold-over' cankers." The writer is likewise guilty of having made a similar statement in a former publication, not upon its own authority however, but from information furnished him by a well known horticulturalist, familiar with Colorado conditions. Everywhere the tendency has been to underestimate the prevalence of hold-over blight, in spite of the recognized fact that were it not for this form of the disease, blight could not be carried from one season to another.

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* Italics by author.

Inasmuch as there was no first hand information available on this subject for the higher altitudes, based upon actual laboratory examinations, the writer has undertaken a study of Hold-over Blight as it occurs in the arid climates, with the hope of adding something to our present knowledge, as well as obtaining more exact data than the well meant but too often unreliable facts given by casual observers. It seemed to me that if unfavorable conditions for the survival of bacteria existed anywhere, they should be found here, in Colorado. The dry winter winds, which often blow for days at a time, are notorious for their destruction of vegetation; the sun shines almost continually throughout the winter months and the temperature often falls as low as —16° F. to —22° F. It would be difficult, indeed, to find natural agents more inimical to microbic life than drying and direct sunlight combined with the possible injury by low temperatures.

The investigation was begun in the summer of 1909, and has been carried on through the winters of 1909-1910 and 1910-1911. In order that we might have hold-over material with which to work which we knew contained the living germs in an active condition during the growing season, we visited certain orchards in the summer time where the blight was in progress and tagged a number of small limbs and twigs varying in size from 1 m.m. to 40 m.m. (3-8 to 1 1-2 in.) in which the blight was unquestionably present. Material from five different orchards has been examined. These orchards, scattered over a wide area, present climatic conditions representative of practically 2000 square miles of fruit land on the Western Slope.

METHODS

Since it has been shown that the bacteria in the hold-over cankers are usually found in the zone just next to the living tissue, we always made it a point, when collecting the specimens to take such sections of the limbs as would include the lower boundary of the blighted, discolored area together with a few inches of the adjacent live wood.

Immediately befor making our isolations, each specimen was wiped thoroughly with a 1-1000 solution of mercuric chloride which was allowed to dry on the surface. This precaution was taken in order to eliminate as far as possible exterior contaminations.

The outer bark was removed with a scalpel, sterilized by boiling, and with a second sterilized scalpel, a diagonal cut was made just above the junction of the blighted and healthy areas, through the cambium into the wood so as to include portions of both the diseased and healthy cambium. Small pieces of both the blackened and normal cambium were removed with aseptic precautions, and dilution plates were made from this material in nutrient agar, +15° Fullers Scale. The plates were kept at 20° C. and after four days, the characteristic Bacillus amylovorus colonies were isolated onto agar slants. In addition to verifying the cultures as B. amylovorus by cultural and

biochemical methods, they were all inoculated into pear seedlings in order to determine their virulence.

EXAMINATION OF MATERIAL.

The first collection of hold-over blight material, tagged during the summer of 1909, was made Feb. 28, 1910. At this time twenty-one specimens were obtained representing three different orchards. From

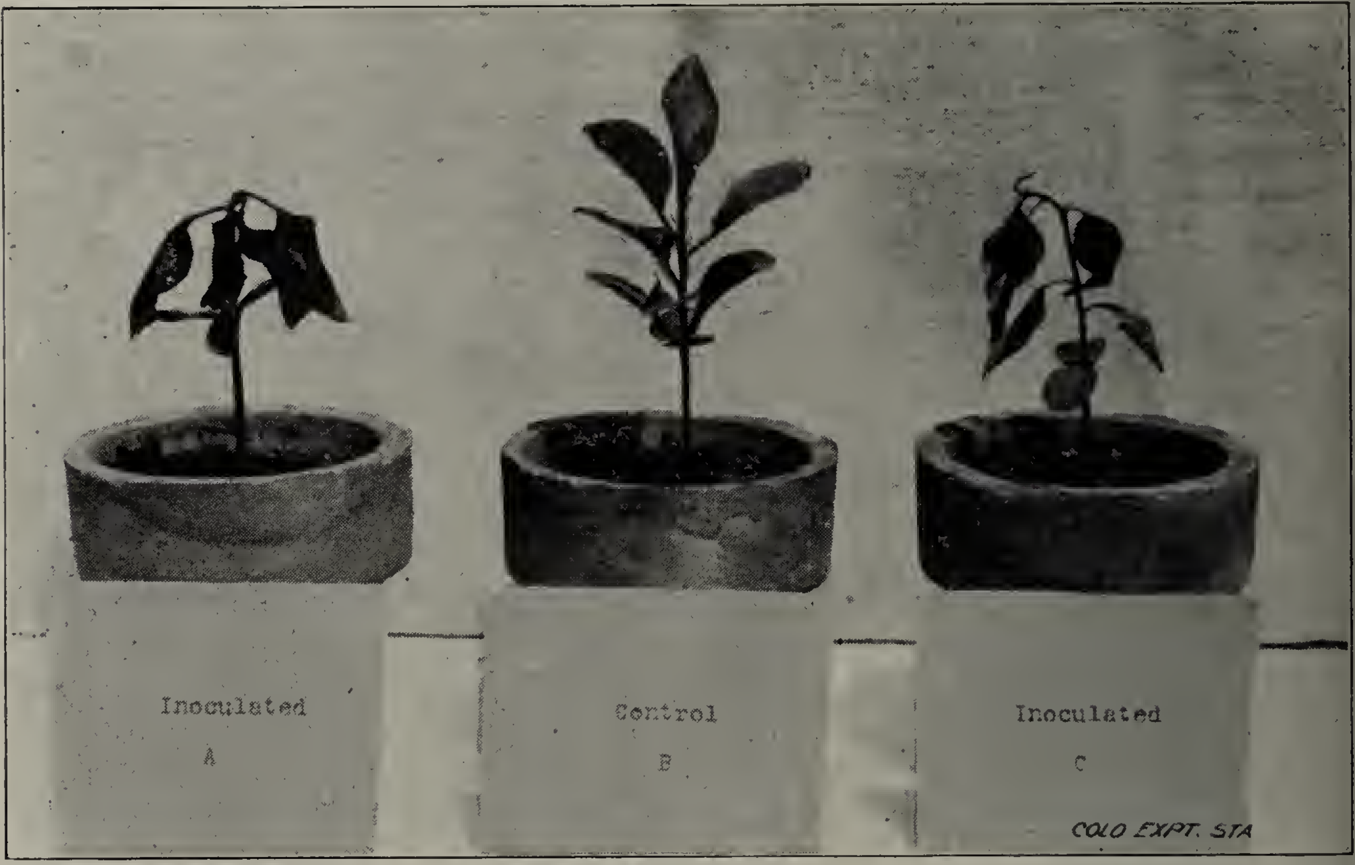

Fig. 1. A and C. Two pear seedlings five days after being inoculated with cultures of B. amylovorus isolated from hold-over canker April 21, 1911

Fig. 2. Hold-over canker on pear twig showing characteristic cracking from which the oozing takes place.

seven of these, or 33.33 per cent, cultures of B. amylovorus were obtained. Three of the limbs were between one, and two and one-half

inches in diameter, and none contained living germs of blight. Ten of the samples varied in diameter from one-half to one inch, and the remaining four were water sprouts. The seven positive cases all occurred in the branches having a diameter of one-half to one inch, and four of these were small yearling twigs of 1909 growth. Only one series was examined for the season of 1909-1910.

On Jan. 26 and 27, 1911, the first collection for the 1910-1911 series was made. The winter was regarded locally as open with considerable snow and rain. At this time twenty-eight samples were secured representing three orchards, two of which were different from those used during 1909-1910. Virulent cultures of Bacillus amylovorus were obtained from six or 21.43 per cent. of these twenty-eight branches, and when 48 hr. cultures of the microorganisms isolated were introduced by needle pricks into the growing tips of pear seedlings, one culture produced typical blackening in four days, two in five days and three in eight days.

The second series was gathered from the same orchards April 12 and 14, 1911. In one of the orchards, the peaches, apricots, cherries and plums were in full bloom. The pear buds had burst but the blossoms were showing no color. Apple buds were swelling. No oozing was observed from the blight cankers. In another orchard, the peaches, apricots and pears were in full bloom; the cherries and plums had already shed their blossoms. Apples were just beginning to show color. No oozing was visible. In the third orchard, peaches and apricots were in bloom, apple buds were about to burst, and the pear buds had opened but were showing no color in the blossoms. There was abundant oozing from the blight cankers on the larger limbs. In all, thirty-four branches and twigs were obtained, twenty-four of which came from the third orchard. The isolations were made April 21 and 22, and of the total number examined in this series, eight or 23.53 per cent. yielded virulent cultures of the blight organism. Five of these produced typical blackening of the pear seedlings in seven days, two in eight days and one in sixteen days.

The following table, No. 1, may be of interest in showing the relation between the occurrence of B. amylovorus and the size of the twig, as well as the character of the microbic flora in the blighted area.

Relation between size of twig and occurrence of B. amylovorus. Material collected April 12, 14, 1911.

(Table No. 1.)

Sample No.	Diameter of twig in millimeters	Presence of B. amylovorus	Character of microbic flora found in blighted wood.
1	12	—	Moulds
2	13	+	Pure culture B. amylovorus
3	16	—	Sterile
4	13	—	Mixed, cream and yellow colonies
5	13	+	Pure culture B. amylovorus
6	10	—	Sterile.
7	14	—	Fluorescent green colonies
8	12	—	Fluorescent green colonies
9	7	—	Sterile.
10	9	+	Mixed, B. amylovor us
11	10	—	Moulds.
12	7	+	Pure culture B. amylovorus
13	12	+	Pure culture B. amylovorus
14	13	+	Pure culture B. amylovorus
51	17	—	Moulds.
16	16	—	Moulds.
17	12	—	Moulds.
18	14	—	Moulds; cream and yellow colonies. No. B. amylovorus.
19	15	+	Pure culture B. amylovorus
20	14	—	Moulds.
21	16	—	Sterile.
22	23	—	Mixed; yellow, green and white colonies
23	30	—	Cream colonies
24	21	—	Moulds
25	23	—	Mixed; yellow and white colonies, moulds
26	47	—	Pale cream colonies
27	36	—	Yellow colonies and moulds
28	30	+	Pure culture B. amylovorus.
29	28	—	Yellow colonies
30	28	—	White stellate colonies
31	38	—	Sterile
32	20	—	Moulds
33	26	—	Sterile
34	23	—	Sterile

Table No. 2 gives the summary of the results of the two years' observations.

Summary of Hold-Over Blight Determinations.
1909-1911.

(Table No. 2.)

Date of Collection	Date of Examination	No. of Twigs Examined	No. containing living B. amylovorus	Per cent containing living B. amylovorus
Feb. 28, 1910	Mar. 4, 1910.	21	7	33.33
Jan. 26, 27. 1911	Feb. 4, 1911.	28	6	21.43
April 2, 4, 1911	Apr. 21, 22, 1911	34	8	23.53

Total number twigs examined, 83.
Total number twigs containing living B. amylovorus, 21.
Total per cent twigs containing living B. amylovorus, 25.3.

Closely related to the question in hand, is the persistence of the blight organism in the pruned twigs. We have always advocated and insisted upon the prompt collection and early destruction of this material because of the supposed danger of the disease being carried to the healthy parts of the tree. Through the courtesy of Prof. H. R. Fulton of the Pennsylvania Experiment Station, I am permitted to give here the results of his recent investigation along this line. While his work has been carried on in Pennsylvania, it is only reasonable to believe that, here again, the dry climate of Colorado would be even more severe upon the bacteria than the moist conditions which prevail in the East.

"Twigs in which the blight bacillus seemed to be actively spreading were selected. These were cut in the ordinary way, and allowed to lie on the ground in thick clover and grass sod during the process of each test. The indication of viability of the organism in each instance was taken to be the inducement of characteristic blighting of succulent twig growth of apple, following its inoculation with bits of inner bark tissue from the tested twigs. These bits of bark were removed with sterilized instruments from three points in the region most recently invaded by the bacteria. They were introduced separately under the young bark of the rapidly growing twigs; and the incisions were covered with paraffin. Such a test was made first of all on the day the tested twigs were cut, in order to be sure of the viability of the organism at the outset. Subsequent tests to determine the time of its persistence were made in the same way after three days, five days, seven days, and in a few instances after a longer period."

"Out of a total of 35 twigs containing viable *Bacillus amylovorus* when cut, thirty-one twigs, or about 9-10 did not contain living bacteria at the end of a week; and most of these became inactive in three to five days. The death of *Bacillus amylovorus* in the twigs was rather uniform in the different tests, and there was not apparent such differ-

ences in the persistenc as might have been expected from the difference in rapidity of drying of the twigs. There was indication of slightly longer persistence in the last two tests when lower temperature was a more conspicuous feature perhaps than increased moisture. Twigs that had been blighted for a longer period did not show any difference in persistence from those of shorter period, the test in each instance being made from portions of the bark recently invaded.

Incidentally it was noted that the dried distal parts of blighted twigs did not, as a rule contain viable blight bacteria. The extent of the zone containing them was not determined, but it evidently varied, and included in general the discolored bark that was apparently moist. The characteristic dried exudation made up of blight bacteria, was tested in several instances, and the bacteria in this seemed regularly to remain alive longer than in adjacent dried bark; and their persistence after the twigs were cut was two to four days longer than of bacteria in recently invaded bark of the same twig.

When one considers the comparatively rapid death of blight bacteria in cut twigs left on the ground, which these tests indicate, and the unlikelihood of any ready transfer of infective material from such a situation to living parts of orchard trees, one is inclined to question the necessity for rigid destruction of cut off twigs. It may, however, be well to defer final judgment until the effect of leaving such material on the ground, has been observed in actual orchard practice."

CONCLUSIONS.

1. In the arid Western climate, the prevalence of Hold-over Blight in the small limbs and twigs of the pear has been underestimated.

2. Under Colorado conditions, at least 20 per cent. of hold-over cankers on the small limbs and twigs contain virulent blight organisms at the time of blossoming.

Bulletin 178 June, 1911

The Agricultural Experiment Station

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THE FIXATION OF NITROGEN

IN SOME COLORADO SOILS

A Further Study

BY

WM. P. HEADDEN

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1910

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THE FIXATION OF NITROGEN IN SOME COLORADO SOILS

A Further Study

By WM. P. HEADDEN

INTRODUCTION.

In Bulletin 155, of this station, I endeavored to demonstrate the occurrence of large quantities of nitrates in some of our Colorado soils by giving a number of analyses showing the presence of phenomenal quantities of these salts. So far as I have been able to learn it will undoubtedly be wise to lay emphasis upon this fact as its importance is fundamental; therefore, I shall give further examples of this occurrence though it seems that it ought to be a superfluous task.

A second point which I endeavored to make perfectly plain was that I was writing not only of an extreme degree of concentration of nitrates in the soil but that this concentration pertained to large areas. Though I endeavored to write very conservatively I mentioned areas of eight, ten and twelve acres, as having been rendered barren by the accumulation of this salt, nitre, which term was used to designate any nitrate, calcic, magnesic, sodic or potassic nitrate, the essential point being the presence of nitric acid.

Again I endeavored to show that any transportation, leaching and subsequent concentration was inadequate to account for the occurrences of these salts, because they occur on high mesas where there is no wash or transportation from higher lands as well as in low lands. In writing of the presence of nitrates in the waters issuing from the shales, I recognized the fact that it might suggest these shales as the source of the nitrates and endeavored to show that such a conclusion would be unwarranted, for the shales in question contain only 0.03 percent of nitrates and the presence of this small amount was probably due to the water from the higher lying mesas where nitrates occur rather abundantly, which fact is stated in Bulletin 155, p. 42, as follows: "The mesas above these shales are cultivated and bad nitre spots occur on top of them, in one case 80 feet above the level at which the water was taken." Further, that nitre spots occur in different geological formations where these shales do not occur, in alluvial deposits and under our ordinary prairie conditions; in other words, the shales, considered as a source of nitre, would not be available for the explanation of the greater part of the occurrences and we are compelled, on account of their insufficiency, to seek for a more generally occurring source or a cause sufficient to account for all the occurrences, assuming that they have a common cause, which is reasonable, at least, until we are sure that they have different causes in different places.

The relation of seepage to these occurrences of nitre was also discussed and the statement was made that the nitre is associated with a rather uniform and abundant supply of moisture but that in really wet soils it does not appear; on the other hand, at least one instance of its occurrence in well drained land was specifically mentioned and described, as follows: "A small piece of land, a sandy loam, near and some 12 or 15 feet above the river has a dark brown color and has not been productive for several years. This land has received good cultivation, the application of much barnyard manure and excessive irrigation in the hope that the "black alkali" would be washed out." In describing Orchard No. 4, I stated that this land is quite high and slopes to the west and south. Again I mention its occurring on hillsides, which was done to convey to the mind of the reader that the locations in which we meet these occurrences are so varied that it would be doing violence to the facts to attribute it to seepage. I mentioned the muddy condition of the soil in three cases which I discussed and gave the height of the water table, if it could properly be called such, as five and one-half or six feet, a perfectly safe depth for all ordinary vegetation. This question was investigated at various seasons of the year without results, materially contributing toward a solution of the problem. The very first question suggesting itself in connection with the troubles described in Bulletin 155, and one which every intelligent ranchman investigates, is the question of water and if the solution of the difficulties were to be found in an excess of water in the soil the ranchmen themselves would long since have found it out, but even in cases in which I have thought it possible or even probable that the soil water might be too abundant, I have been informed by persons of very different character that the water plane varied from 12 to 16 or more feet throughout a whole section of country. These people had dug cisterns and wells and made other excavations, and their information on this subject is fairly reliable. I am convinced that the muddy condition of the three soils described is rather a result of the presence of the nitre than a cause of the trouble.

Bulletin 160 is more than a popular restatement of the facts of Bulletin 155, in that it gives our observations upon the orchards from September of 1909 till May of 1910, which gave us no reason for modifying any view expressed in Bulletin 155, except to intimate rather strongly, that the seriousness of the problem was even greater than had been suggested in Bulletin 155.

In describing the condition of the land I again state more strongly than before: "This condition then is not restricted to low lands; is not dependent upon the variety of the soil unless it be within very wide limits, and is not due to bad drainage though it is often observed in low, moist places." In order to convey a

definite measure of its effects it was stated: "I know of one orchard from which 110 trees have been removed this—the spring of 1910—another from which 200, and still another from which more than 200 trees have been removed or are dead."

I gave what appeared to me a justifying reason for considering orchard trees rather than some other crop. My reason was essentially this, that the effect, in the case of the apple tree in particular, is so wide-spread and disastrous that no one conversant with the facts can doubt the existence of a very serious evil, and inasmuch as our orchards both old and young received almost constant attention and care, I wanted to appeal to both the knowledge and interests of the people, as I realized that I was setting forth rather startling facts, and if the people did not believe in the existence of the evil any explanation of the cause would be nothing more than an appeal to their imaginations. That I was justified in this course is fully shown by the doubts entertained by persons who are not ranchmen and orchardists but men of education, experience and mature judgment, some of whom when asked for an opinion have reserved their judgment on the ground that they had never seen such conditions as were described.

It was not my intention in either of the bulletins previously issued on this subject to venture upon the question pertaining to the possible influence of the excessive formation of nitre in the soil upon any of the general crops but it seemed wise to make some tentative statements regarding this feature of the question and the beet crop was mentioned as one which had, possibly, already shown the effects of a continuous and, in the aggregate, excessive supply of this salt. Of course, such a bold suggestion would meet with doubt if not with less kindly treatment. I purposely held close to demonstrable facts, i. e., the presence of unprecedented quantities of nitrates, sometimes confined to small areas but often extending so as to involve eight, ten, twenty or even forty acres, or the death of many apple trees scattered over a large territory, all attacked and dying in a similar manner, or the increasing nonproductiveness of the land till total barrenness ensued. I suggested as a cause for the accumulation of these nitrates the action of certain groups of bacteria only after I had considered every other source which might prove sufficient to explain all of the facts. While the facts adduced as the basis of this claim may be open to some objections, I believe that we shall be able to show that it is a fact that the nitrates are formed in situ, but I shall leave the explanation of this fact and the questions, whence comes the energy; are the azotobacter species alone responsible for the fixation and nitrification or do other groups of bacteria play a more important part than the azotobacter in converting the nitrogen into nitric acid, for others to solve.

The task which I set myself is to show that the nitrate *is*

formed in situ, but this is only a part of the purpose of the present bulletin. It is intended to extend the discussion of the occurrences of these nitre spots and to describe further the effects of this nitre on the soil and plants. In a subsequent bulletin I intend to take up, in some degree of fullness, its effect upon the growth and quality of the sugar beet, more especially upon its composition.

Case No. 5—The orchards and localities described in Bulletin 155 will not be treated of in this bulletin except as further observations made since Bulletin 155 was published may seem to justify, when they will be referred to by the number under which they were described in that bulletin. We will continue the numbers beginning with orchard or case No. 5. I visited this orchard, quite a large one, on the 12th of June, 1909. I did not obtain the age of the trees but they were probably not less than 15 years old. They had been sprayed heavily, especially in 1903, 1904 and 1905. There were a few trees in the orchard with corroded crowns, very probably due to arsenic, but arsenic had nothing to do with the trouble that we went to investigate. The condition of the orchard was, in the main, good; we, however, found twelve large trees in a group, with brown leaves and the trees appeared to be dead. The rest of the orchard was in good condition, the foliage was of full size and healthy in color. We learned from the owner that these trees had appeared perfectly healthy until within a fortnight or less. The orchard had not been irrigated as I inferred from the appearance of the surface of the ground in parts of the orchard, but this was due to the overflow of a waste ditch some weeks previous to this time. The soil about these trees was mealy on the surface and felt soft under the foot. We dug a hole near to one of these dead trees, five and a half feet deep. The soil was moist but there was no free water at this depth. I took a sample of soil from a place near to one of the very badly affected trees to a depth of one foot. The water-soluble in this sample amounted to 0.57 percent. It was rich in nitric acid but owing to the small amount of residue at our disposal no analysis of it was attempted.

It was evident that these trees were not drowned by the rising of ground water nor killed by an excessive amount of ordinary alkali. I next visited this orchard on September 21, 1909. More trees were affected and there was no improvement in the condition of any trees previously observed. On November 3 I again visited it and dug a hole five and a half feet deep near a tree which was dying. The soil was wet but there was no free water, and this was at the season when the fall irrigation of adjoining lands was being applied. A sample of soil was taken from the surface of this ground to a depth of two inches. The surface was slightly incrusted and mealy underneath but there was no efflorescence. In places the surface appeared wet, evidently due to the presence of

deliquescent salts. The sample of surface soil taken on this date contained 5.91 percent soluble in water.

ANALYSIS*	I Water-Soluble Laboratory No. 873 Nov. 23, 1909 Percent
Calcic sulfate	20.360
Magnesic sulfate	6.655
Magnesic chlorid	0.459
Potassic chlorid	1.292
Sodic chlorid	45.229
Sodic nitrate	25.843
Iron and Aluminic oxid	Trace
Manganic oxid	0.032
Silicic acid	0.130
	100.000

This analysis shows the presence of five tons of nitrates, calculated as sodic nitrate in the top two inches of soil or a trifle over thirty tons calculated on an acre-foot.

I again visited this orchard for the purpose of further investigating the question of the water table on December 3. It has been stated that on June 12 we dug a hole five and a half feet deep near a tree which had recently died. On this date, December 3, we dug another hole at the same place six and a half feet deep. The ground was quite wet at this depth but there was no free water. It has already been stated that the soil is a sandy loam, and it was sandier at this depth. Another hole was dug seven and a

*In this bulletin all of the analyses have been calculated to one hundred. This has been done because we believe that the reader will be able to compare the results more easily, as they are all reduced to a common basis, i. e., parts per hundred of the dry residue—also to save space. Many of the samples presented difficulties, mostly owing to the presence of very deliquescent and easily decomposed salts such as the chlorids and nitrates of calcium and magnesium—and in a few cases of large quantities of organic matter.

The nitric acid determination in a few samples is undoubtedly too low because of the presence of magnesic nitrate and the continued drying necessary to obtain a manageable residue. Some of these samples intumesced badly and emitted an acid odor, during which some loss of nitric and hydrochloric acids probably took place. The nitric acid was determined in duplicate in every case as NO, and the NO absorbed by means of a recently boiled $FeCl_2$ solution. I believe that the results as presented in the analyses represent the composition of the water-soluble portion of the soils in a water-free condition with a very fair degree of accuracy. It is not, however, intended to assert that the nitric acid is all combined with one base, as appears in the greater number of the analyses, as for instance as sodic nitrate. This is simply a convenient manner of combining it and may in some cases be correct, but in many of these residues it is probably not correct.

There is almost uniformly a trace of manganese in these aqueous extracts, but it has been disregarded for the most part as it seldom exceeds two or three hundredths of one percent.

half feet deep at the same place, where we dug to the depth of five and a half feet on November 3. At this depth the ground was very wet, even muddy. We waited a short time to see whether any free water would flow in but it did not. On May 14, 1910, I again visited this orchard. The condition of the orchard was very bad, many trees had been removed and many more were dying. On June 11, 1910, almost exactly a year subsequent to the first observations made on these dying trees, I visited it again. The orchard was ruined; most of the trees were dead; and worse yet, the land, so far as we can now see, is as thoroughly ruined as the orchard. A large portion of this orchard—six to eight acres—has been dug up.

The orchard immediately south of this one is in a very bad condition; it is, for the most part, dead. No samples of either the soil or the ground water were taken at this place. The owner, a man of considerable education, is fully convinced that the trouble is not due to excessive water in the soil.

The following samples of surface soil from Orchard No. 5 will convey a better idea of the conditions existing in this soil than any words describing them. In No. 947-a the water-soluble equalled 11.6; in No. 959, 3.4; in No. 995, 12.79, and in No. 1013, 7.20 percent of the air-dried soil.

ANALYSES	II	III	IV	V
	Water-Soluble Laboratory No. 947a May 14, 1910	Water-Soluble Laboratory No. 159 June 11, 1910	Water-Soluble Laboratory No. 995 Aug. 25, 1910	Water-Soluble Laboratory No. 1013 Sept. 13, 1910
	Percent	Percent	Percent	Percent
Calcic sulfate	18.437	20.437	8.219	9.123
Calcic chlorid	14.778	———	17.005	20.415
Magnesic sulfate	———	5.999	———	———
Magnesic chlorid	10.474	———	12.295	10.658
Potassic sulfate	———	1.447	———	———
Potassic chlorid	2.273	———	1.434	1.575
Sodic sulfate	———	15.104	———	———
Sodic chlorid	13.726	35.416	8.747	27.708
Sodic nitrate	39.790	21.303	52.071	30.350
Iron and Aluminic oxids	0.132	0.149	0.090	0.051
Silicic acid	0.210	0.235	0.139	0.111
	100.000	100.000	100.000	100.000

The dates on which the various samples were taken, extending over two years and representing the months of May, June, August, September and November, show that the condition is a persistent one, and while it may vary from month to month there was a very dangerous quantity of nitrates in this soil throughout the whole period.

In 1909 I produced decided injury to four-year-old trees by the addition of five pounds of nitre to the soil, within a radius of

about twenty inches around the trunk of the tree. No one has to my knowledge demonstrated how small an amount of nitrates may do injury to an apple tree if placed within reach of its feeding roots, especially at the period of its most rapid growth. My experiments were made to see whether this amount would produce any effect upon the trees and to observe how this effect expressed itself and not with the idea of determining the tolerance of the apple tree for this particular salt, sodic nitrate.

The trees in this orchard, especially the first ones attacked, twelve or more in number, did not turn yellow, dwindle and gradually succumb, but, though they were in full leaf and appeared vigorous and healthy, the leaves suddenly turned brown and drooped and the trees died outright within ten days or a fortnight. As the trees in this orchard continued to die throughout the season of 1910 it may serve a purpose to calculate the amount of nitrate available to an ordinary-sized tree, fifteen years of age. The roots of such a tree will occupy an area represented by a circle forty feet in diameter, at least; this will give approximately 1,200 square feet of surface. All of the feeding roots in this orchard were found to be within two feet of the surface. The sample of soil was taken to a depth of two inches or one-sixth of a foot and there would be two hundred cubic feet of such dirt to furnish nitrates to the tree. Assuming a cubic foot of this sandy soil to weigh ninety pounds, we have 18,000 pounds of nitre-rich soil, 11.6 percent of which is soluble in water, or 2,088 pounds, four-tenths of which (39.97 percent) or 835 pounds consists of sodic nitrate or its equivalent in other nitrates.

In this calculation I have assumed that the soil below a depth of two inches furnished no nitrates—which is altogether contrary to the facts. It may, however, serve to convey a clear idea of the large amount of nitrates present within the feeding areas of these trees, 832 pounds in this case, ready to be moved downward and supplied to the feeding roots, all of which are within two feet of the surface, by a rain or irrigation or any other agent, possibly even by cultivation of the soil. This was in May when the trees were feeding actively. Our sample taken in August is still worse, 12.8 percent soluble in water, placing 2,304 pounds of salts above the roots of the tree with 1,178 pounds of sodic nitrate or its equivalent. When we incorporated five pounds of sodic nitrate with the soil about a four-year-old tree and watered it, we injured some of the branches; when we incorporated twenty-five pounds and irrigated it we killed the tree in four days. It is not probable that every tree in this orchard had either 1,178 or even 832 pounds of sodic nitrate at its disposal but all of the trees in this area, some eight acres or more, died and were dug up between May 1909 and March 1911. Another way to convey an idea of the large quantities of nitrates

with which we are dealing is to express it in tons per acre-foot as was done in Bulletin 155 or in the surface two inches of soil. The figures obtained for the August sample gave us 22.1 tons in the top two inches of soil for each acre of land or practically 133 tons per acre-foot which corresponds to 6.66 percent of the weight of the air-dried soil. These trees had lived and grown healthily, some of them I would say vigorously, for fourteen or fifteen years, till May, 1909, when twelve or more of them died within a fortnight without previously having shown any distress and within the next eighteen months eight acres or more of this orchard died.

Case No. 6— My first observations on this orchard were made in 1908. Some trees scattered throughout the orchard had already died and been removed. While I was satisfied that arsenic had caused the death of some of them, it evidently had had nothing to do with the death of others. At first I had considered seepage to be the possible cause of the trouble. The water plane, however, was stated to be from seven to ten feet below the surface. Subsequent investigation indicated that this statement was correct, besides my knowledge of this section of the country would lead me to expect the water plane to be not less than six feet below the surface. I do not believe that the water plane rises and falls through any great distance, at least I have found no indications of such a fact. The owner stated that the ground turned brown and then things died. The aspect of the land is to the south with a slight depression running northeast and southwest through the orchard. There are some differences of level in different parts of the orchard. I have no notes in regard to the amount of these differences but they are not great, possibly a maximum of twelve feet. A cellar is located near the middle of the east side of the orchard and it is five feet deep with a hole dug about the middle of it. This hole had some water in it in the spring of 1909. More trees, eighteen of them, died during the latter part of the season of 1908 and these were removed in the spring of 1909 after which the orchard was plowed and this portion of it sowed to wheat. The wheat was a total failure as almost none of it came up. The owner attributed this to his failure to irrigate the land. My opinion is that it was not his fault. By July 1, 1909, the orchard was very badly burned and by October a portion of it was dead and leafless. Photographs of this orchard were used as illustrations in Bulletin 155, Plates III and IV, page 26. As Plate III shows the healthy condition of that portion of the orchard which formed the background of Plate IV, which gives an excellent idea of how the orchard had suffered, they are reproduced in this connection as Plate I. This represents the destruction wrought in a single season. These trees, 110 of them, were removed in the spring of 1910, and on July 14, the date of my next visit, the

affected area had been extended very noticeably and many more trees were dying.

A set of soil samples was taken from this orchard May 14, 1909, representing the surface soil, also the first, second and third foot. In taking these samples we dug a hole about four and one-half feet deep. No water was met with but we filled up the hole as soon as we had procured the samples and did not wait to see whether any water would run in or not. These samples were extracted with water and gave as follows, the surface soil 4.68, the first foot 1.86, and second foot 2.09 and the third foot 1.509 percent soluble in water.

ANALYSES	VI	VII	VIII	IX
	Water-Soluble Laboratory No. 784 Surface Soil May, 1909	Water-Soluble Laboratory No. 785 First Foot of Soil	Water-Soluble Laboratory No. 736 Second Foot May, 1909	Water-Soluble Laboratory No. 787 Third Foot May, 1909
	Percent	Percent	Percent	Percent
Calcic sulfate	29.607	69.830	57.250	37.344
Calcic carbonate	9.679	——	——	——
Calcic chlorid	6.686	——	——	——
Magnesic sulfate	——	5.071	13.249	15.311
Magnesic chlorid	9.729	3.203	3.442	0.670
Potassic chlorid	3.549	1.736	1.265	1.229
Sodic chlorid	32.834	18.780	22.601	41.448
Sodic nitrate	7.239	0.709	1.591	3.402
Iron and Aluminic oxid	0.145	——	——	——
Manganic oxid	0.234	——	——	0.282
Silicic acid	0.298	0.671	0.602	0.314
	100.000	100.000	100.000	100.000

ANALYSES	X	XI	XII
	Soil Laboratory No. 785 First Foot	Soil Laboratory No. 786 Seeond Foot	Soil Laboratory No. 787 Third Foot
	Percent	Percent	Percent
Insoluble	64.820	66.674	68.027
Silicic acid, soluble	5.650	2.927	2.131
Sulfuric acid	0.810	1.282	0.503
Chlorin	0.890	0.333	0.308
Phosphoric acid	0.180	0.242	0.267
Carbonic acid	7.040	7.370	6.636
Lime	7.180	7.730	6.590
Magnesia	2.190	2.967	2.961
Sodic oxid	0.840	0.402	0.494
Potassic oxid	0.690	0.595	0.661
Ferric oxid	3.110	2.890	3.170
Aluminic oxid	2.250	1.354	2.030
Manganic oxid (br)	——	0.210	0.220
Moisture at 100°	1.470	1.260	1.498
Ignition	2.970	(3.838)	(4.573)
Sum	100.090	100.074	100.069
O equiv. to chlorin	0.200	0.074	0.069
Total	99.890	100.000	100.000
Humus	0.248	——	——
Humus ash	0.194	——	——
Total nitrogen	0.072	0.056	0.055

There is nothing in the results obtained by the ordinary agricultural analyses of this soil to indicate anything unusual unless it be the small amount of total nitrogen present. The method followed in these analyses was the conventional one, digestion with hydric chlorid sp. g. 1.115, etc., and the nitrogen determined by the Kjeldahl method modified for the determination of nitric acid. No. 785 is the first foot of soil from which the surface portion was scraped off in order to obtain the soil without incrustation of effloresced salts, and we have, as shown by the aqueous extract of this sample, a remarkably small amount of nitrates while the second and third foot show decidedly increased quantities. The third foot contains only a little less than the top two inches but is relatively only one-sixth as rich. We have for the top two inches 2,257 pounds, for the next foot 528 pounds, for the second foot 1,332 pounds and for the third foot 2,053 pounds per acre. I do not believe that the nitre in the third foot of soil participates largely in doing injury to the trees unless it be brought nearer to the surface, say within two feet of the surface, by capillarity or some other agent, so that we cannot take this third foot into our reckoning except as a possible source of nitrates. The top twenty-six inches of this soil, however, contained at the time the samples were taken, in May, a little better than two tons of sodic nitrate, a comparatively moderate quantity, provided that these salts were not concentrated within the feeding zone of the roots. But, even as the case stands, there is, assuming 80 trees to the acre, fifty pounds of sodic nitrate to the tree, taking the soil to the depth of twenty-six inches and supposing that the succeeding foot with twenty-five pounds more for each tree does not in any way enter into the problem. I do not know how the amount of nitrates varied during the ensuing season, but, if they increased in this soil as they were observed to do in some others, the aggregate amount present during the season must have been at least twice as great as that given but, be this as it may, 110 trees occupying a continuous area about the point where these samples were taken died within the next four months in the same manner as that in which the trees we poisoned with sodic nitrate and as thousands of others, in lands richer in nitrates, died. The question of the amount of nitrates necessary to kill apple trees would be an interesting one to answer but it is not the object of this bulletin. There are also other questions involved, for instance, to determine the maximum quantity of nitrates available to trees in such lands at any one time, for, it is evident, that if a fatal quantity were available for only a few days, perhaps one day, it might suffice to kill them. We killed a tree in four days. Again it would be interesting to know whether a tree, say 15 years of age, would tolerate more saltpetre in September than in April, May or June,

owing to its different vegetative activity. But none of these questions fall within the scope of this bulletin.

Fortunately we can, in part, answer a question suggested above in regard to whether the nitrates have increased, as we have a sample of the surface soil taken very nearly from the same point at which the surface sample was taken May 9, 1909. The second sample was taken May 3, 1911.

This land is, at this writing, planted to winter wheat. The plants are largely confined to the bottoms of the creases or irrigating furrows. The crests of the creases or spaces between the furrows are mostly bare. The owner thinks that this may possibly be due to the lack of a sufficient amount of moisture to germinate the seed. I do not think that this was the case, as the irrigating furrows are rather close together and as he gave it a fair irrigation, it is not probable that there was so great a lack of moisture as to cause a general failure of germination between the furrows. I think it much more probable that the water flowing in the furrows removed the nitrates far enough from the seed to permit their germination and the establishment of the young plant.

The condition of these plants at this time, May 3, 1911, was very interesting; the plants were large and vigorous, and had an intensely green color, but so many of them were burning that the tips, already browned back on the leaf for three or four, or even more inches, presented a marked contrast to the otherwise luxuriant looking wheat, and it is a question whether even these thoroughly well established plants will endure it to mature their grain.

ANALYSIS	XIII Water-Soluble Laboratory No. 1069 May 3, 1911 Percent
Calcic sulfate	14.155
Calcic chlorid	20.275
Magnesic chlorid	12.885
Potassic chlorid	1.360
Sodic chlorid	38.496
Sodic nitrate	12.621
Iron and Alumina	Trace
	100.000

Sample 784 was taken in May of 1909. Sample No. 1069 was taken in May, 1911. The ground from which No. 1069 was gathered, in 1911, was occupied by healthy trees in 1908 and the early part of 1909, but these trees died in 1909 and were removed in the spring of 1910. Stated otherwise, this land prior to the summer of 1909 had never contained enough nitrates to injure the trees which had been growing in it for fifteen or more years, but the accumulation of the nitrates in 1909 passed the limits of

tolerance for the apple trees and they died. By May 3, 1911, this land, which showed no nitrate at this place in 1909, was brown and mealy and wheat was not able to grow healthily in it and on a great deal of the ground not at all. A surface sample, taken in May, 1909, from a part of this orchard where the trees had died, gave 4.68 percent soluble in water which contained nitric acid corresponding to 7.239 percent of sodic nitrate. A similar sample, taken in May, 1911, from ground which did not show this trouble in 1909, gave 6.80 percent soluble in water containing nitric acid equal to 12.621 percent of sodic nitrate. As these samples represent the surface portion, approximately to a depth of two inches, we will compare them; in 1909 the surface two inches of a portion of this land where the trees had died contained 2,258.8 pounds of sodic nitrate per acre, whereas a portion of the same land which did not contain enough nitrates in May, 1909 to kill the trees contained in May, 1911, 3,433 pounds, a gain of 1,174 pounds per acre in the surface two inches in two years on the supposition that this soil was really as rich in 1909 as the ground in which the trees had already died, which is not true, so the gain actually exceeds 1,174 pounds of nitrate in two years. Evaporation of ground waters from the surface of this soil is wholly inadequate to account for such an accumulation as this. I will give figures and statements showing that it is very liberal to assume the presence of 0.3 p. p. m. of nitric nitrogen in the ground water and I will support this with further figures in subsequent paragraphs. But 0.3 p. p. m. of nitric nitrogen is equivalent to 1.8 p. p. m. of sodic nitrate equal to 4.896 pounds per acre foot. On the assumption that this nitrate has been brought to this land by the ground waters and deposited by its evaporation we would have to evaporate 239.8 acre-feet in two years or 119.9 acre-feet per annum—whereas our actual evaporation from a free water surface is forty-one inches or it would take 70 years to effect the evaporation from a free water surface required by our supposition in two years from a soil surface. There is another feature of which we cannot lose sight; our ground waters are rich in other dissolved salts and these must be accounted for in some way. Our ground waters seldom carry less than 100 grains per imperial gallon or 1,429 p. p. m. or 3,858 pounds per acre-foot of water according to which we would have to account for 925,920 pounds or 463 tons of alkalis on every acre of this ground which, assuming the alkalis to be as dense as the soil itself, would cover the soil one-quarter foot deep every two years which is evidently contrary to the facts. Our soils are rich in soluble salts, that is salts soluble in water, but they are not covered nor even mixed with any such quantities as this supposition shows must be present. This particular soil is quite rich but we found in the surface soil, two inches deep, in 1909, 4.68 percent and

in the first foot 1.86, in the second 2.09 and in the third 1.509 percent—which the analyses show to be very largely calcic sulfate.

These statements, as well as the following considerations, apply to every individual case considered in this bulletin. The ground waters are wholly inadequate to transport the nitrate, for we have no 120 acre-feet of ground water per annum nor is there any land surface from which to obtain the nitrates. The whole of the irrigated lands in some sections are more or less affected and it is wholly gratuitous to even suggest our native prairies and mountain sides as a source of these nitrates. Our river waters, even those used for irrigation, contain very little nitric nitrogen from 0.00 to 0.4 p. p. m. Our virgin soils show only 8.000 p. p. m. of nitric nitrogen as a maximum—and even this is subject to appropriation by plants and reduction in the soil, so that even though very large areas were to be leached out or washed off this source could scarcely be soberly appealed to as the source of these nitrates.

Case No. 7—This orchard showed the first bad burning about the middle of May, 1909, shortly after the orchard had been heated to protect the crop against frost, about April 27. The trees had continued to grow steadily worse and the owner at first feared that the injury was due either wholly or in part to the gases given off during the combustion of the coal used in heating the orchard. To this question there was a very direct answer, i. e., the water sprouts which had grown since the heating were burning badly.

This orchard presents, in regard to soil conditions, a strong contrast to the last one mentioned, and to all others heretofore mentioned, except Orchard No. 5. The soil is sandy, inclining in some parts of the orchard to a clayey loam. The attack began a little to the east of the center of the orchard. This part of the orchard is not lower than the rest of it. The owner has sprayed very heavily some seasons and is still a heavy sprayer. There were some girdled trees in the orchard but the arsenic had nothing to do with the burning. This burning is quite distinct from a spray burn. We dug a hole near to one of the burned trees five and one-half feet deep. The orchard had been recently irrigated but we found no more than a desirable degree of moisture at this depth. A sample of soil was taken at this time. The depth to which it was taken is not stated in my notes. The water-soluble equaled 0.187 percent. No analysis was made of this material beyond a nitric acid determination which showed an amount corresponding to 5.412 percent of sodic nitrate or 0.01 percent of the air-dried soil, a small amount, still it equals about 22 pounds to a tree taking the soil to a depth of two feet. The family is supplied with water stored in a cistern which is 10 feet deep. I was informed that they did not strike water in digging it. The age of

this orchard was 18 years. The owner stated that he had observed a Lawver tree about three years previous to this time which turned brown on one side but recovered so that it grew healthily the following year. Some of these burned trees put forth a few new leaves which had a whitish yellow color and soon died. We visited this orchard again on November 3, when we found a number of the trees evidently dead, and again on December 3, 1909, when with the help of the owner we dug out a number of the roots and again sought to ascertain the depth of the water table. We followed the roots from the trunk of the tree as far as possible. In one case this proved to be 21 feet at which point we lost it because it had turned abruptly toward the surface and had been cut off by the plow. The root had become so small at this point and other roots were so numerous that we could not identify it with certainty. We attempted to follow other roots but we found it very difficult to do, owing to the presence of such a number of other roots and the smallness of the extreme ends. The greatest depth attained by those that we followed was two feet below the surface. All of the little roots that we encountered in this attempt seemed to be perfectly healthy even to the minute fibrous roots. Th greatest distance that we followed any root was 23 feet. There were only a very few fibrous roots as deep as 30 inches, almost all of them being within 24 inches of the surface. These roots which we dug out belonged to the trees which had been badly burned. Not only were the roots of the trees apparently healthy but the crowns and larger roots near the trunk were also apparently perfect. The owner suggested that we dig up one of these trees but as the root system seemed to be in such good condition I suggested that it would be better to let it and the rest of them stand till the next spring, 1910, and see whether they would recover or not. The trees were left standing, but they did not recover—they had already been killed.

Wishing to dispel, if possible, all doubts in regard to the part played by the ground water in the death of these trees, we dug another hole near one of the trees just described. The orchard had received a heavy irrigation on September 25, and the next few days following. The ditch, 120 feet east of where we dug this second hole, had stood full of water for three or more weeks in September. It had overflowed and formed a small pond at the edge of the orchard. The soil at the place where we dug this hole was sandy and we encountered the water plane at five and one-half feet, or two and three-quarters feet below the deepest roots that we observed. On May 14, 1910, four days after the orchard had been irrigated, I found the leaves on some trees burning. There seemed to be so good as no recovery from the injury of 1909. On June 11 the condition of this orchard was very bad indeed, and

PLATE I.—See page 10.

evidently growing worse. It was evident that a considerable number of trees would succumb, indeed some were already dead and conditions were not improving in the least. The water table was not within five feet of the surface in an adjoining orchard though recently irrigated. The affected area had extended so as to embrace nearly the whole of this old orchard. There is a young orchard on still higher land which is not yet affected. By September 13, 1910, the old part of the orchard was practically ruined. The water table at that time was not within five and a half feet of the surface. In this orchard we have a decidedly sandy soil, inclining to a clayey loam in places, and not an adobe soil which often becomes muddy at comparatively shallow depths as described in Bulletin 155. At no time have we found the water table less than five and a quarter feet below the surface and practically no roots at a greater depth than two and a half feet, and but few below two feet. The surface of this soil is brown and mealy, and is rich in nitrates and the orchard is in very bad condition.

The orchard immediately east of this presents the same conditions of soil with the water plane deeper than five and a half feet below the surface. The top soil is brown and mealy and many of the trees are dead, some having died in 1909 and others in 1910.

The orchard immediately to the south is worse than either of these as the trees are practically all gone.

This orchard, No. 7, has been given in such detail because it is the first old orchard planted on this type of soil with the water table well below the surface, to which we have made so many visits, and in which we have been able to watch the progress of the trouble. Orchard No. 5 went rather more rapidly, as did also No. 6. The soil of Orchard No. 5 is likewise a sandy loam and the water table is likewise low, but the land itself is possibly a little less favorably located than that of Orchard No. 7.

I will give but two analyses of soil from Orchard No. 7, or rather I will give analyses of the water-soluble portions of surface samples, one taken from near a young tree, seven or eight years old, which was burned but slightly at the close of the season, September 13, 1910, No. 1014; the other No. 1071, taken in May, 1911. The water-soluble of No. 1014 equalled 2.974, and of No. 1071 equalled 6.276 percent.

ANALYSES

	XIV Water-Soluble Laboratory No. 1014 Percent	XV Water-Soluble Laboratory No. 1071 Percent
Calcic sulfate	23.270	25.022
Calcic chlorid	17.550	24.160
Magnesic chlorid	15.930	17.420
Potassic chlorid	4.044	4.023
Sodic chlorid	35.432	24.268
Sodic nitrate	1.420	4.686
Iron and Aluminic oxid	2.069	0.162
Silicic acid	0.285	0.258
	100.000	100.000

This orchard was beginning to burn in the early part of June, 1911, earlier than in preceding years.

Case No. 8—This is a young orchard set in 1908. The history of the ground as given to me is as follows: Prior to 1904 the whole piece of land was productive; in this year a brown patch appeared and the land became unproductive. It was covered thickly with manure in 1904 and again in 1906. The conditions were not improved. In 1908 it was set to orchard and planted to beets. The trees did not do at all well in this area and some of them died. The beets came up very poorly; they were replanted twice and the stand was still very poor, the beets produced being over-grown and having large tops. My information is that the quality was poor. In my field notes mention is made of the fact that the land outside of this area appears as heavily charged with alkali as the area itself, but the owner asserted that this land was very productive and subsequent observations lead me to believe that the statement is correct. This land was irrigated ten or twelve times during the season, each time excessively in the hope that the "black alkali" might thereby be removed—to use the owner's language: "I washed it till the soil was white." I took a set of samples from this land in April, 1909. The soil is sandy loam with a more sandy subsoil. I dug to a depth of five feet, without further change in the soil and without striking the water table. This place is practically on the river bank where the soil section is sand lying on top of coarse gravel. The river bed is now from twelve to fifteen feet below the level of this land and the brown mealy soil occurs within fifty feet of the edge of the bank. It is scarcely possible to obtain better drainage conditions than these. This is, in fact, the reason for my making particular mention of this place. At first I thought that this condition was in general largely due to an excess of moisture, such an excess as to be of itself injurious to vegetation, but I do not find such to be the case. Orchards No. 5 and No. 7 are also on sandy loam soils and not adobe soils which retain water persistently. They are, however,

not drained so well as this land, lying as it does on the river bank, the most remote part of it being scarcely more than three hundred feet from the river, and twelve or fifteen feet above its bed. The trees that had died in 1908 were replaced in the spring of 1909. On May 6, I have noted that the brown area appears in good condition but that the trees are not doing well. November 2, same year, I visited this place again and noted that the apple trees in this bad spot had died. The ground had been recently disced and seemed in good condition, but those spots which had escaped being stirred were brown and mealy. Some one attempted to conduct a truck garden immediately north of and contiguous to this ground, beginning in 1907. At this time, November, 1909, it was almost black in color, encrusted a little and mealy underneath.

In July, 1910, the condition of the land was worse than I had ever seen it, not only the trees but also corn and peas showing the effects of the nitre.

One sample of soil was sent to me in February, 1908, presumably taken to a depth of from eight to twelve inches according to directions. This sample yielded 1.262 percent of salts soluble in water, containing nitric acid equivalent to 11.230 percent of the soluble salts or 0.142 percent of the air-dried soil, or 5,680 pounds, nearly three tons per acre-foot. Other samples of soil were collected at this place at subsequent times, April 21, 1908, April 6, 1909 and November 2, 1909.

Further back from the river we have seepage beyond a question. We found the water table at from two to eleven feet, but the water at the latter depth was under considerable hydrostatic pressure and rose in the holes dug to within two and a half feet of the surface. The party who procured some of the water samples for me described this fact as follows: "It kept getting wetter until I struck gravel, at four feet, when the water rushed in and bubbled up as if under pressure. The water rose sixteen inches in thirty minutes, and finally stood at two and one half feet below the surface." The gravel here referred to is very probably the natural drainage into the river and this water passes beneath the land which we have just described.

These general conditions are given only because they contribute to a better understanding of the question. I have been repeatedly asked whether the seepage water does not bring these nitrates into these localities. This question has been raised by the character of the samples of drain and ground waters whose analyses are given in Bulletin 155, p. 27 *et seq.* I stated in connection with them that the presence of nitrates in the seepage water issuing from the shales, for instance, was easily accounted for by the cultivation of the higher lying mesas, on which these nitre spots occur and in some cases are even prevalent. If the seepage water from any

section were wholly derived from such a source there would be nitre introduced into the seeped lands with the water unless the nitrates were reduced or otherwise removed. This, however, is not the case. The seepage in almost every case is made up of the leakage from irrigating canals and ditches or from excessive irrigation. The lands before being brought under irrigation do not contain nitrates or even nitrogen in quantities worthy of note, in fact the supply of this element is quite limited. The waters used for irrigation are taken from our rivers and lesser streams which are supplied by the snows which fall in our mountain sections. While there may be a few exceptions to this statement, it is in the main correct, and no exception of any weight, so far as I can recall, applies in any measure to any of the lands treated of in Bulletin 155 or which will be considered in this.

I know of no lands anywhere which would be more likely to be affected in such a manner than land immediately north and a little east of this particular tract, and concerning the seeped or water-logged condition of which no question can fairly be entertained. As already stated we encountered water as close as two and a half feet of the surface, which fact alone does not prove that the ground is necessarily unproductive; but this ground was nearly barren. It had been in alfalfa, a little of which was still living at the time of which I am writing. The soil was wet and heavily charged with the ordinary alkali of the section. Three samples of this ground water were taken in November and December of 1907. The alkali in this immediate section is higher in chlorin than is usual. This is one of the places referred to in Bulletin 155 as especially rich, so rich in chlorin that the salt, sodic chlorid, present may possibly be injurious to vegetation. Inasmuch as this question has been suggested and as I know of no place more unfavorable to my views regarding the subject, I will give analyses of soils, of samples of alkali and of the three samples of ground waters from this section. They are not from the same spot but were taken from places near one another, within one quarter of a mile and not more than one half mile from Orchard No. 8. The alkali and the soil were taken from land that had at one time been cultivated. The rows were still visible and the manure in the rows had not yet rotted. The ground was at this time bare but not brown and greasy in appearance. I do not know whether anything could have been made to grow on it or not. No attempt to do so has been made at any time during the past three years. The surface portion of this soil was extremely rich in alkali. I observed, at the time these samples were taken, in some depressions in this field, crystals of sodic sulfate from one and a half to two and a half inches long. The soil sample, taken to a depth of one foot, yielded 2.45 percent soluble in water. The second and third

foot were taken as one sample and gave 4.27 percent soluble in water.

ANALYSES	XVI Water-Soluble Labratory No. 632 First Foot Percent	XVII Water-Soluble Labratory No. 633 Second and Third Foot Percent
Calcic sulfate	41.882	42.122
Magnesic sulfate	8.747	18.397
Sodic sulfate	10.847	5.747
Sodic chlorid	34.014	28.019
Sodic silicate	1.276	1.479
Manganic oxid	——	0.070
Ignition	3.234	4.184
	100.000	100.000

These water-soluble portions were tested for nitric acid and there was not enough present to give a reaction with ferrous sulfate and sulfuric acid. That the water-soluble should be made up so largely of calcic sulfate is what one would expect, because this salt, as the mineral gypsum, can be seen forming veinlets and small aggregations throughout the mass of the soil. This is the case to a greater extent in the second and third than in the first foot. The quantity of sodic chlorid is larger than usual but is still within the limits of tolerance for almost all plants.

ANALYSES	XVIII Soil Laboratory No. 632 First Foot Percent	XIX Soil Laboratory No. 633 Second and Third Foot Percent
Sand	48.951	47.747
Silicic acid (sol.)	22.377	17.945
Sulfuric acid	0.708	3.194
Chlorin	0.387	0.599
Phosphoric acid	0.156	0.217
Carbonic acid	3.968	3.709
Lime	4.624	5.877
Magnesia	2.650	2.864
Sodic oxid	0.740	1.033
Potassic oxid	1.082	1.356
Ferric oxid	4.344	3.374
Aluminic oxid	5.286	7.405
Manganic oxid	0.168	0.675
Water expelled at 100°	1.707	2.933
Ignition	2.986	(1.207)
Sum	100.134	100.135
Oxygen equiv. to chlorin	0.087	0.135
Total	100.047	100.000

Another soil in which the conditions were worse even than in the preceding is represented by the next sample. This ground

had been an alfalfa field and a few of the plants were not yet entirely dead. The crowns and roots showed that it had recently been a good stand and that the plants had been large. The water table was in this case within two and a half feet of the surface.

ANALYSIS

	XX Soil Laboratory No. 625
	Percent
Sand	66.822
Silicic acid (sol.)	11.303
Sulfuric acid	0.042
Chlorin	0.703
Phosphoric acid	0.042
Carbonic acid	4.458
Lime	4.294
Magnesia	2.339
Sodic oxid	0.653
Potassic oxid	0.660
Ferric oxid	3.089
Aluminic oxid	2.005
Manganic oxid	0.051
Water at 100°	1.250
Ignition	2.192
Sum	100.663
Oxygen equiv. chlorin	0.159
Total	100.504

ANALYSIS

	XXI Alkali Laboratory No. 622
	Percent
Calcic sulfate	6.893
Magnesic sulfate	17.373
Sodic sulfate	27.868
Sodic chlorid	43.466
Sodic silicate	0.316
Ignition, etc.	(4.384)
	100.000

The following three samples are ground waters taken within the area under consideration, all of them taken in November and December of 1907.

ANALYSES	XXII Ground Water Laboratory No. 647	XXIII Ground Water Laboratory No. 668	XXIV Ground Water Laboratory No. 669
Total solids in grains per Imp. Gal.	883.54	1052.29	1076.81
	Percent	Percent	Percent
Calcic sulfate	19.726	14.318	10.976
Magnesic sulfate	22.618	24.687	30.105
Magnesic carbonate	———	———	1.827
Potassic sulfate	0.700	0.967	———
Potassic carbonate	———	———	0.715
Potassic chlorid	———	———	0.308
Sodic sulfate	5.744	11.060	———
Sodic carbonate	2.431	3.872	———
Sodic chlorid	44.670	40.405	49.732
Sodic silicate	0.869	0.841	0.149
Manganic oxid (br)	0.097	———	0.059
Ignition	(3.143)	(3.850)	(6.129)
	100.000	100.000	100.000

There is not enough nitric acid in this alkali or in any of these soil extracts or water residues to give, when as much as one-half to one gram of the dry residue is taken, a satisfactory test with ferrous sulfate and sulfuric acid, and some of them give no reaction with diphenylamine and sulfuric acid.

There is not another instance of the occurrence of nitre within this state which is so favorably located for justifying the theory of concentration from adjoining lands as this one and it is for this reason that I have set forth these facts pertaining to the composition of the alkali, the soils to a depth of three feet, the aqueous extracts made from these soils, and the solids held in solution by the ground waters. The results of the analyses show that even if the soil of Orchard No. 8 had been saturated with the ground waters which had drained through this area it would not, at this time, have become impregnated with nitrates but with sulfates and chlorids. These ground waters, however, do not saturate the nitre soil and it is a question whether they ever rise or in any other manner find their way into it and consequently cannot possibly account for the nitrates for two reasons; first, there was so good as no nitrates in either the soil lying to the north of this orchard or in the alkali which, in places, was abundant on its surface, or in the ground waters, which came near to the surface in parts of the area; second, because these ground waters do no find their way into this orchard soil which is underlaid by gravel and is well drained.

A great deal has been said and somewhat written about alkali and seepage. I will remark in passing that while seepage and alkali usually accompany one another they constitute two distinct subjects. We have many examples of lands rich in alkali which are not now wet enough to be objectionable, and I shall in a subsequent bulletin give specific data which are the basis for the

statement that both water and alkali may be quite abundant and the land still be productive. These are very undesirable conditions but they alone are not so fatal as some people would have us think. In all events they constitute problems distinctly different from the nitre problem, and are not so closely related to it as even I at first thought. My original description of these occurrences of nitre showed that I considered it as dependent upon a constant, optimum supply of moisture. This condition is met with near the outer edges of wet places. The nitrates do not appear where there is a great excess of water. On the other hand they are not confined to places which are seeped, of which fact the orchard in question, No. 8, is a good example, as is also Orchard No. 7. In fact, Orchards 1 and 2, Bulletin 155, are the only cases given in which an excessively wet condition of the soil was observed but no proper water table was found in these at a depth of six to six and a half feet. Such, then, are the conditions surrounding this orchard No. 8, and the little garden tract immediately north of it. I have already stated that the soil is sandy and the section at the river bank, which practically forms the southern boundary of the field, shows a section of twelve to fifteen feet, the upper six or seven feet of which is sand while the lower portion is a coarse river gravel. A sample of surface soil, taken two inches deep in April, 1909, gave 4.42 percent of the air-dried soil as soluble in water. Sample No. 875 contained 10.86 percent of salts soluble in water.

ANALYSES	XXV Water-Soluble Laboratory No. 772 April, 1909 Percent	XXVI Water Soluble Laboratory No. 875 Nov, 1909 Percent
Calcic sulfate	35.266	24.810
Magnesic sulfate	3.197	3.238
Magnesic chlorid	14.673	15.235
Potassic chlorid	2.109	1.911
Sodic chlorid	33.841	50.704
Sodic nitrate	10.508	3.944
Iron and Aluminic oxid		0.158
Sodic silicate	0.406	
	100.000	100.000

We have in No. 772 the nitrates equivalent to 0.464 percent of the top two inches of the soil, equal to 3,096 pounds or one and one-half tons of nitrates per acre taken to a depth of two inches or at the rate of nine tons per acre-foot. In No. 875 we find the sodic nitrate equal to 0.424 percent of the surface soil, giving us practically the same amount of nitrates per acre as No. 772.

ANALYSES	XXVII Water-Soluble Laboratory No. 877 Surface Soil	XXVIII Water-Soluble Laboratory No. 778 Sample taken 8 inches deep top 2 inches, removed April, 1909
	Percent	Percent
Calcic sulfate	15.345	38.643
Calcic chlorid	3.521	———
Magnesic chlorid	14.611	———
Magnesic sulfate	———	11.082
Potassic chlorid	2.215	———
Potassic sulfate	———	9.500
Sodic sulfate	———	2.473
Sodic chlorid	51.474	33.854
Sodic nitrate	12.596	3.784
Iron and Aluminic oxid	Trace	0.100
Manganic oxid	0.094	0.042
Silicic acid	0.144	0.522
	100.000	100.000

In this case we find in April, 1909, that the top two inches of this soil showed the presence of one and a half tons of sodic nitrate. Another sample taken in November of the same year, and perhaps one hundred and fifty feet north of where the sample was taken in April, gives us essentially the same amount, one and a half tons in the top two inches. But the same depth of soil taken November 2, the same year and very nearly at the same point where the April sample had been taken, showed the presence of almost four tons, 3.978 tons, of nitrate in the top two inches per acre. A sample of this soil taken from the third to the tenth inch inclusive in April, 1909, or eight inches of the soil, after the top two inches had been removed, showed the presence of 2,306 pounds, a little over one ton to the acre taken to this depth, eight inches. This land had been excessively irrigated ten or twelve times during the season of 1908 with the idea of washing out the alkali. There were no signs of trouble in this land prior to 1904 according to the statement of its former owner.

Sample No. 875 was taken from ground which had been used as a truck garden in 1908. I scarcely need to state that the truck garden was a failure. This young orchard, Case No. 8, is used for the same purpose, i. e., gardening, and with excellent results except in this brown area. Analyses XV to XXVII inclusive are analyses of the alkali, the soil, and the ground waters which lie to the north and east of this land, not quite surrounding it but including the land through which the ground waters would have to move in order to reach this orchard. These samples were taken in 1907 and contained no nitrates—or only such traces as may be found by extracting any soil. I may state, though it is very evident, that neither Bulletin 155 nor this one deals at all with such quan-

tities of nitric acid or nitrates as are usually understood when nitrates in the soil are spoken of, but of the occurrence of such unusual quantities as to be fatal or injurious to vegetation. I shall endeavor to deal with the general condition, of which only extreme cases are presented in this bulletin, in a subsequent one.

The analyses of the adjacent, almost circumjacent soils, the alkalis and the ground waters have been given to show that they have nothing to do with the conditions in this orchard soil, and especially nothing to do with the nitrates. Apropos to the influence of the drainage and the character of the soil upon this question, we have chosen one sample of dark brown surface soil from this orchard collected within fifty feet of the edge of the river bank, and a second one, also a dark brown surface soil from another piece of land of which no other mention is made. Both of these pieces of land are naturally well drained but in addition to this there are four tile drains in the second piece which contains only thirteen acres. One of these drains was carrying about two inches of water while the other two that I saw were not running at all. There is still another drain on the land adjoining this on the east, which was carrying a large flow of water. The owner of the land stated that all of the drains carry water after he irrigates the land, showing conclusively that the land drains freely. The soil is sandy, very similar to that of Case 8, with which we have joined it. I was informed that some of the drains have been laid four years. Laboratory No. 1067 is a sample from Case 8, collected March 27, 1911, fifty feet from the river bank. We give two analyses of this sample, one of the water-soluble portion, the other a mechanical analysis of the soil. The water-soluble in this sample equaled 8.165 percent of the air-dried soil. Laboratory No. 1076 is a similar sample collected from the drained land and also within fifty feet of the river bank and not less than twelve feet above the river bed. These soils are so similar that the mechanical analysis of the one faithfully represents the other. The water-soluble in No. 1076 equalled 9.882 percent of the air-dried sample.

ANALYSES	XXIX Water-Soluble Laboratory No. 1067 March 27, 1911 Percent	XXX Water-Soluble Laboratory No. 1076 May 2, 1911 Percent
Calcic sulfate	21.826	19.494
Calcic chlorid	23.971	1.647
Magnesic chlorid	20.534	16.435
Potassic chlorid	2.880	1.716
Sodic chlorid	26.846	57.106
Sodic nitrate	3.807	3.374
Iron and Aluminic oxid	———	0.101
Silicic acid	0.136	0.127
	100.000	100.000

ANALYSES	XXXI Mechanical Analysis Laboratory No. 1067 Percent
Above 1.0 mm. dia.	0.708
1.0 mm.-0.5 mm.	1.222
0.5 mm.-0.25 mm.	9.851
0.25 mm.-0.05 mm.	47.582
0.05 mm.-0.01 mm.	21.021
0.01 mm.-Clay	8.419
Clay, by diff.	11.197
	100.000

	XXXII Drain Water Labratory No. 1201 Percent
Calcic sulfate	21.380
Magnesic sulfate	25.249
Potassic sulfate	0.695
Sodic sulfate	5.119
Sodic chlorid	42.874
Sodic carbonate	4.683
	100.000

	p. p. m.
Total solids	8489.00000
Ammonia	0.01800
Nitrogen as nitrites	0.00003
Nitrogen as nitrates	0.10000

The two pieces of land discussed at this time differ only in this, that one of them has been drained for four years and the other is not artificially drained at all. We observe that the soil consists of 47 percent of fine and very fine sand, further that there is 21 percent of silt and a fair amount of clay. The samples 1067 and 1076 are alike in location so that they are perfectly comparable in every respect except that the land represented by No. 1076 has been drained for four years; some of the drains having been put in recently, others of them at earlier dates. The samples are both surface samples, that from the undrained land contains 8.165 and the drained land 9.882 percent of water-soluble salts which in both cases consist of sulfates, chlorids and nitrates. The amounts of nitrates contained in the samples give us for No. 1067, 2,072 pounds calculated for the top two inches, while No. 1076 gives us 2,223 pounds calculated for a like depth, or calculated for the acre-foot of soil, we have 12,432 and 13,336 pounds respectively.

The drain water was collected from an east and west drain crossing the northern end, while the sample of soil, No. 1076, was collected from the southeastern corner of this land. It may be further stated that there are two other east and west drains between the drain from which the water sample was taken and the point where we took the soil sample and in addition to this there is a north and south drain running within a few feet east of this latter point which is itself not more than fifty feet north of the river bank.

I may also add that the soil on top of and along the side of this north and south drain is in the same condition as the sample actually taken.

The object in stating these details is evident, i. e., to show that these conditions are independent of the seepage question and

that drainage is not of itself and necessarily a cure, and still further to show that these nitrates are not deposited by the evaporation of ground water coming from other lands. The owner explained to me that the depth of the drains vary—which is evident without statement—but he added that the gravel below the soil is very irregular in its surface so that the depth of gravel penetrated by the drains is quite different. We will not consider any greater depth of soil than is represented by our samples, i. e., two inches, but we will calculate how much of this drain water would be required to furnish the nitrate which we actually find in these two inches of soil, and we will take this as 2,150 pounds. The samples of soil and drain water were taken in May, 1911. The drain water contains 0.1 part per million of nitric nitrogen equivalent to 0.6 part per million sodic nitrate; taking an acre-foot of water at 2.7 million pounds it gives us 1.62 pounds of nitrates per acre-foot of water and we would have to evaporate 1,327 acre-feet of this drain water to obtain this 2,150 pounds of nitrates which we find present at this time. The evaporation of this amount of water would require, assuming that the annual evaporation amounted to sixty inches (at Ft. Collins it is only 41 inches) two hundred and sixty-five years. This drain water carries 8,489 parts of total solids per million which, calculated on the 1,327 acre-feet of water necessary to yield the 2,150 pounds of nitrates, would yield 30,414,840 pounds of salts, a quantity sufficient to cover the land more than seven feet deep, if we suppose them to have the same density as the soil itself.

The changes in the conditions of these soils have taken place within the past few, say six, years, and these conclusions to which we are forced if we suppose that these nitrates have their origin in the evaporation of the ground waters are evidently false. We know that no 1,327 acre-feet of water have evaporated to dryness on this land in this time and it is evident that our country is not covered nearly eight feet deep with calcic chlorid and other salts and we are likewise quite as sure that land which up to six years ago, and this assumed period is from three to six times as long as the facts indicate, has not been two hundred and sixty-five years in going to the bad.

I have described the condition of the land north and east of north of this orchard, designated No. 8, and from one-fourth to one-half mile distant, as having the natural color of ordinary adobe soil, in 1907 and 1908, with an abundance of ordinary white alkali in its surface portions, and stated that sulfate of soda crystals up to two and a half inches long occurred in the lower portions of this land, especially in depressions in the surface soil. In the spring of 1911 practically the whole surface in this land is dark brown in color and greasy in appearance. I dug a hole four

and a half feet deep in a low spot in the field, and while the ground was wet, there was no free water. It is very probable that the water table in this land varies exceedingly from place to place, indeed it is very probable that one might choose a place and dig a hole twelve or more feet deep and find no portion of it wetter than the top six inches, possibly not as wet, and at another point encounter water within three feet or less of the surface; further, these points may be close together in the field. A sample of surface soil with its alkali was taken at the point where I dug the hole four and a half feet deep; this was mixed with samples of like soil from other parts of the field. This sample is so rich in nitrates that the aqueous extract from two grams of it gives a strong reaction for nitric acid. In 1907 the extract of the soil gave none. There are many square miles of such lands. The following analysis is to be compared with analyses of Laboratory Nos. 622 and 632. This land was already seeped in 1907, almost if not quite as badly then as now. The water-soluble in sample No. 1070 equalled 18.176 percent.

ANALYSIS XXXIII

	Water-Soluble Laboratory No. 1070 Surface Soil May 2, 1911
	Percent
Calcic sulfate	21.104
Magnesic sulfate	15.766
Potassic sulfate	2.391
Sodic sulfate	1.676
Sodic chlorid	58.263
Sodic nitrate	0.518
Iron and Aluminic oxid	0.052
Silicic acid	0.230
	100.000

The percentage of sodic nitrate in this analysis is not large compared with some of our samples, but compared with the quantities present in 1907 it is quite as striking as the changes in the appearance of the land itself which was then the uniform gray of our adobe soils, now it looks as though it had been irregularly moistened with a heavy crude oil and though the large quantities of salts present are not favorable to an abundant development of nitrates we now find nitrates present at the rate of one and nine-tenths tons per acre-foot where, four years before, we found none.

Case No. 9—I visited this orchard for the first time May 18, 1910. The age of the trees still living was twenty-eight years. No disease had appeared in the orchard till the season of 1909. During this season about two and one-half acres of the orchard, two hundred trees, showed serious trouble and died in about six weeks. These trees had been removed from the orchard at this time, May 18, 1910, and used to stop the washing away of the

river bank. The trees were not only old, they were also large, some of them measuring fifteen inches in diameter, and the owner stated that he had gathered from them crops of fifty boxes to the tree. The soil is a light sandy loam with a decidedly sandy subsoil, underlaid by gravel at a depth of from six to eight feet. We dug a hole five feet deep eight days after irrigation and found the ground only fairly moist. The drainage of this land is so free that when the northern part of it is irrigated freely a well in the southern part will show a rise of water within a few hours, less than twenty-four, and falls quickly.

After the dead trees were removed the land was prepared for planting to some crop. It appeared to be in the most excellent condition. Corn was subsquently planted but the stand obtained was very poor indeed. The owner attributed this to the quality of the seed which he said appeared to be good but it did not come up. I dug up samples of the seed corn which were thoroughly preserved, the grains were full, plump, fine-looking ones and there was an abundance of moisture to permit germination. This soil was brown and mealy on the surface. A sample was taken at this place where the corn had failed to come up and an analysis of it will be given later. This land continued to become more and more mealy and the remaining portion of the orchard became involved to a greater extent as the season passed, till, by the middle of September, at least one-half of the total area, five acres or more, was decidedly brown, and a further number of these old apple trees were affected. The corn crop was a complete failure. The sample taken, 989, represented the surface soil of a considerable area and was made by taking portions at various places, mixing as thoroughly as possible and then cutting it down to a manageable size; the depth of the soil represented is four and a half inches. The water-soluble equalled in No. 989, 2.884; in No. 892, 2.398; in No. 1074, 3.909, and in No. 989a, 6.96 percent of the air-dried soil.

ANALYSES	XXXIV Water-Soluble Laboratory No. 982 July 19, 1910 Percent	XXXV Water-Soluble Laboratory No. 989 July 11, 1910 Percent	XXXVI Water-Soluble Laboratory No. 989a Sept. 12, 1910 Percent	XXXVII Water-Soluble Laboratory No. 1074 May 7, 1911 Percent
Calcic sulfate	30.263	24.664	8.756	37.982
Calcic chlorid	5.888	9.298	14.117	———
Magnesic sulfate	———	———	———	1.726
Magnesic chlorid	14.930	15.217	9.217	10.817
Potassic chlorid	3.190	2.861	1.632	3.898
Sodic chlorid	41.757	43.832	60.219	35.135
Sodic nitrate	3.605	3.033	5.906	9.889
Iron and Aluminic oxids	0.152	0.138	0.084	0.087
Silicic acid	0.215	0.232	0.069	0.466
Carbon	———	0.725	———	———
	100.000	100.000	100.000	100.000

The soil designated as Laboratory No. 989a, was very brown on its surface, and when exposed to the atmosphere, after drying at 100°, absorbed enough moisture to cause it to adhere so tenaciously that one could press it into clumps in the hand which retained the form of the fingers. The aqueous extract had a brownish yellow color which became decidedly brown on evaporation. This color continued to go into solution even after the chlorids and sulfates had been completely washed out. The color could scarcely have been due to humus in the presence of such quantities of lime salts, besides the soil is poor in humus and the strong brown color on the surface of this soil is not due to this cause. It would have been difficult to have obtained a sample of this soil entirely free from the azotobacter pigments in which to determine the humus. Prof. Sackett has obtained cultures showing that the azotobacter pigments are soluble in water. This accounts for the deportment of this sample.

The mechanical analysis given for Laboratory No. 1067 is quite as applicable to the sample No. 989 as to the one of which it was made and likewise the agricultural chemical analysis is quite as applicable to 1067. The localities are probably as much as two miles apart but the soils are similar in location and character.

ANALYSIS	XXXVIII Soil, top four inches Laboratory No. 989 Percent
Sand	59.993
Silicic acid (sol.)	15.000
Sulfuric acid	0.430
Carbonic acid	3.450
Chlorin	1.561
Phosphoric acid	0.220
Lime	4.890
Magnesia	1.783
Potash	0.794
Soda	1.557
Ferric oxid	3.542
Aluminic oxid	2.189
Manganic oxid	0.370
Water at 100° C.	0.500
Ignition	(4.072)
Sum	100.351
O. equivalent to chlorin	0.351
Total	100.000
Total nitrogen	0.118

The ordinary agricultural analysis of this sample indicates that it is an excellent soil, which inference would be further justified by the mechanical analysis of No. 1067. While these inferences are fully justified by the analytical results and even further by the fact that all that was said of the preceding case,

Case No. 8, in regard to the drainage or water conditions, the simple fact remains that the twenty-eight-year-old apple trees, beginning in 1909, have practically all died, and the corn planted in 1910 was a total failure as a crop. When we consider samples 982, 989 and 989a, we see that the surface five inches of the soil contains from 1,440 to 1,660 pounds of sodic or other nitrate per acre. Approximately this depth was taken because these samples were taken after the corn had failed to come up and it was thought that the results obtained would give us an idea of the lower limits of nitrates which would prohibit germination. We knew perfectly well that this would not establish anything beyond giving us an idea of what quantity will prohibit the germination of corn. The quantity which effects this is less than 0.09 percent of the soil. Sample No. 1074 is a surface sample from the place where oats, potatoes, etc., will not grow but pear trees continue to do quite well. We find that the top two inches of this land carries 2,578 pounds of nitrates per acre—I surmise that the pear trees endure this apparently better than apple trees and the other plants because they feed at greater depths and it may be true, as it actually seemed to be, that they are more tolerant of these salts than the other plants, but they are not immune for I have seen pear trees that have been killed just as the apple trees were killed. I repeat that the facts adduced pertaining to the two pieces of land mentioned under Case No. 8 apply with full force to Case No. 9, in fact these cases might have been discussed as a single one if the distance between them and the age of the orchard in Case 9 had not made it ill advised to do so.

Case No. 10—This is a peach orchard and the part referred to in this paragraph has been reset a number of times, the last time to pear trees, but without success. The part very badly affected is about one-third of an acre in extent, but there is probably three acres in all that is damaged by these conditions. This soil is a sandy loam three feet deep, underlaid by a coarse granitic gravel. The surface is brown and there is no vegetation. The land is no lower than the surrounding country. There was no excessive water in this or in adjacent lands. Two samples of soil were taken, one to a depth of one foot, No. 874; this sample showed the presence of 1.127 percent soluble in water; the other, No. 880, was a surface sample taken to a depth of one and one-half inches which showed the presence of 5.528 percent of the air-dried sample soluble in water.

ANALYSES	XXXIX Water-Soluble Laboratory No. 880 Nov. 2, 1909 Percent	XL Water-Soluble Laboratory No. 874 Nov. 2, 1909 Percent
Calcic sulfate	30.513	52.204
Calcic chlorid	2.412	———
Magnesic sulfate	———	6.991
Magnesic chlorid	13.990	10.594
Magnesic nitrate	5.210	———
Potassic chlorid	———	5.199
Potassic nitrate	6.809	———
Sodic chlorid	———	1.276
Sodic nitrate	40.841	22.981
Iron and Aluminic oxid	0.092	0.393
Manganic oxid	Trace	Trace
Silicic acid	0.133	———
Loss	———	0.362
	100.000	100.000

This is perhaps the most surprising occurrence of this difficulty that I have to record. This land is most favorably located, but it is not the only piece of land affected in this manner in this section. The owner told me that he had removed an old orchard principally because the varieties were poor, and that he had not been able to get the young trees to live. In the case of No. 880 we have been compelled to unite a part of the nitric acid with magnesium and potassium and we have 52.86 percent of the total soluble salts composed of nitrates, giving us the top inch and a half, the depth to which the sample was taken, 14,610 pounds to the acre—7.3 tons, or 116,880 pounds of nitrates to the acre-foot of such soil—58.4 tons.

Sample No. 874 represents the next succeeding foot with 5.7 tons per acre-foot. We actually have in the top thirteen and one-half inches of this land 13 tons of nitrates, principally nitrate of soda. This land is wholly barren. There is a cellar at the edge of this piece of land, six feet deep, the bottom of which is in the coarse gravel previously mentioned. In March, 1911, the bottom of this cellar was not only dry but actually dusty when stirred.

Most of the pear trees set in the spring of 1910 died before mid-summer and but few survived till the spring of 1911. The pear tree seems to be very tolerant of these salts, especially so when once established.

Case No. 11—This orchard is located near a ditch. The trees were attacked in July or August and died outright. The land had been heavily manured and when I visited it, it had just been irrigated and was, of course, wet on the surface. We dug a hole five and a half feet deep and found no signs of any excess of water. The soil is a sandy loam. I took two samples, one of

them one and a half inches deep; this gave 1.45 percent soluble in water and showed very little nitric acid. The other sample was taken to a greater depth, eight inches, and showed the presence of 1.762 percent water-soluble and a very decided quantity of nitric acid.

ANALYSES	XLI Water-Soluble Laboratory No. 876 Percent	XLII Water-Soluble Laboratory No. 877a Percent
Calcic sulfate	80.355	43.457
Magnesic sulfate	8.591	19.658
Potassic sulfate	2.998	10.206
Potassic chlorid	4.458	———
Sodic sulfate	———	1.030
Sodic chlorid	2.302	13.494
Sodic nitrate	———	11.373
Iron and Aluminic oxid	0.193	0.147
Silicic acid	1.103	0.635
	100.000	100.000

It is seldom that we have so great a difference in the character of the soluble salts in samples of soil from the same place. This is probably due to the heavy irrigation that this land had just received. It had apparently moved the whole of the nitric acid down into the soil to a greater depth than one and a half inches and most of the sodic and potassic salts with it. In this respect these two analyses are quite interesting. The eight-inch sample shows the presence of 5,344 pounds per acre in this section of soil, or a little over four tons to the acre-foot.

Case No. 12—This is one of the worst cases that I have observed. The soil is sandy and the orchard is contiguous to Orchard No. 11 and west of it. In June, 1910, I observed the beginning of a very general burning in the orchard and a few trees, perhaps twelve to twenty, were already dead or in a bad condition. I spoke to the owner in regard to the matter but he thought that it was a case of spray burning and attributed the trouble to a faultily prepared lead arsenate. He was very positive in regard to the matter. I saw this orchard in September when it was in a very bad condition, probably upwards of six acres being involved and very many of the trees will not survive the season. The conditions of this orchard are the same as in Orchard No. 11, and there is no question of drainage or alkali. Both orchards are fairly old ones, the oldest trees being probably not less than sixteen years and the youngest twelve to fourteen years old. When the owner of Orchard No. 12 became convinced that something more serious than spray burning had happened to his trees he manured the land and irrigated heavily. The development of this orchard

in 1911 would have been interesting to watch, if the owner had not removed the six-or-eight-acre block of trees.

Cases Nos. 13 and 14— These orchards have suffered greatly, especially No. 14, during the past seasons; fifty acres or more in the two orchards have been seriously affected, and many trees have died. The soil conditions vary considerably in different portions of these properties; some of the land, a small portion, is low, but the most of it is well located. I have joined these properties because they are close together but not adjoining and because they present, in the main, essentially the same problems. They are both pretty well protected against seepage, being nearly if not the highest ground under irrigation in that section. One of them has a very deep wash on the north and west sides of it and a system of drains running through the lower land. The questions pertaining to Orchard No. 13 may be more involved than any which I have heretofore described, but this is not the case with No. 14. I gave the analyses of two samples of drain water from Orchard No. 13 in Bulletin 155. They were as follows:

ANALYSES	XLIII	XLIV
	Residue from Drain Water Laboratory No. 610	Residue from Drain Water Laboratory No. 792
	Percent	Percent
Calcic sulfate	23.202	22.352
Magnesic sulfate	36.662	31.586
Potassic sulfate	0.705	1.502
Sodic sulfate	29.991	24.775
Sodic chlorid	2.863	9.050
Sodic carbonate	4.093	4.120
Sodic nitrate	2.275	6.500
Silicic acid	0.209	0.115
	100.000	100.000

The solids in these waters are essentially sulfates. The small amount of carbonates indicates the amount of this salt to be expected in the soil. We find in the drain waters from soils more favorably conditioned than this one, from seven to twenty-three percent of the total solids held in solution consisting of this salt, carbonate. I unfortunately do not know the amount of water discharged by the respective drains at the time the samples were taken but the total solids varied only slightly. No. 610 contained 637.3 grains of total solids per imperial gallon; No. 792, 622.65 grains. A drain water flowing from a piece of strongly alkalized ground contained 113.8 grains, sample taken in April. Another sample from the same ground, taken in July, contained 72.8 grains, and another in February three years later contained 160.5 grains. Another drain water flowing from a somewhat alkalized area, but

by no means a very bad one, contained 62.2 grains per imperial gallon.

The nitric nitrogen was determined in two of these samples, one containing 0.24 part, the other 0.48 part per million, whereas No. 610 carried 34.5 parts and No. 792 carried 96.37 parts nitric nitrogen per million, or No. 610 carried 143.8 times as much as the first drain water and No. 792 carried 200 times as much as the second drain water. While the percentage of sodic carbonate in the residue obtained from these waters varies greatly, the actual amount of sodic carbonate per million of water is nearly the same, for instance, 323, 355, and 364 parts per million, which serves to show how very high the nitrates in these two waters are in comparison with the amounts present in drain waters from ordinary alkali land.

The flow from these drains undoubtedly varies with the irrigating season. I do not know whether the drains are stopped up or not but they discharged no water for several months during the spring of 1911.

The land included in Orchard No. 13, as stated before, presents involved conditions. A portion of it was seeped and badly so, ten or twelve years ago, and was drained a little over ten years ago. This land in the meantime has been benefited to such an extent that good crops of wheat, forty-five bushels per acre, have been harvested from it. There are portions of this area through which the drain passes and which one would think should receive the full benefit of the drainage which, though not wetter than other portions, are unproductive. I took samples from such places several years ago. In taking these samples I recognized three conditions, a thin crust on the surface, of which 8.317 percent was soluble in water; a portion immediately underneath this crust, of which 7.680 percent was soluble, and the soil proper, the first foot of which after the two preceding portions had been removed, gave me 1.330 percent soluble in water.

ANALYSES	XLV	XLVI	XLVII
	Water-Soluble Laboratory No. 819 Crust on surface	Water-Soluble Laboratory No. 818 Portion under the crust	Water-Soluble Laboratory No. 816 Soil one foot deep
	Percent	Percent	Percent
Calcic sulfate	13.926	51.858	19.863
Magnesic sulfate	20.841	11.043	14.511
Potassic sulfate	2.027	2.084	2.611
Sodic sulfate	44.021	16.734	52.334
Sodic carbonate	——	0.872	——
Sodic chlorid	16.427	16.793	8.795
Sodic nitrate	2.525	2.435	1.646
Iron and Aluminic oxid	0.067	0.032	0.098
Silicic acid	0.166	0.149	0.142
	100.000	100.000	100.000

A very large portion of this orchard, at least thirty-five acres, has been removed. Some of the trees may have been killed by an excess of water. I am fully prepared to accept this as an adequate and very probable cause in some cases and yet the question presents itself why they should have lived to be fourteen or sixteen years old and die several, eight or ten, years after the drains were put in and the water had been removed. I realize that it is exceedingly difficult to present all of the facts and the questions which arise in this connection so that persons who have never seen these conditions can apprehend them. But though the facts may be perplexing and it may be difficult to give a satisfactory reason why seepage should kill these trees, I am still thoroughly convinced that excessive water injured some of them. This, however, does not apply to the greater part of this orchard. Almost, but not quite, the highest portion of this orchard with the deep wash, previously referred to, bounding the section on two sides, has suffered severely, in fact, several acres of it, ten or more, have been entirely destroyed. The trees have not been killed by winter injury, nor by arsenic, so far as I have been able to detect and I have tried to determine this point, but a great many of them have been burned and have died just as in the other orchards described. In the summer of 1909 and again in 1910 I watched the progress of the destruction of this orchard, marking trees in May and June to see them dead in August and September.

Samples of the surface soil from the higher sandy portion of the orchard, where the destruction of the trees has been complete, gave the following results: the water-soluble equalled in 815, 0.985, in 1061, 1.467, and in 1075, 8.590 percent of the air-dried sample.

ANALYSES	XLVIII	XLIX	L
	Water-Soluble Laboratory No. 815 June 3, 1909	Water-Soluble Laboratory No. 1061 March 28, 1911	Water-Soluble Laboratory No. 1075 May 2, 1911
	Percent	Percent	Percent
Calcic sulfate	17.521	59.460	28.162
Magnesic sulfate	27.166	15.714	9.470
Magnesic chlorid	———	———	9.141
Potassic sulfate	3.768	3.466	———
Potassic chlorid	———	3.264	3.932
Sodic sulfate	11.925	———	———
Sodic chlorid	18.683	4.540	5.086
Sodic nitrate	20.367	13.057	44.035
Iron and Aluminic oxid	0.065	———	Trace
Silicic acid	0.505	0.499	0.174
	100.000	100.000	100.000

Sample No. 1075 is the surface, mealy portion formed in the irrigating furrows after the last irrigation. This land has been sown to oats this year, 1911, but they are not in good condition.

The water-soluble in this sample equalled 8.590 percent and the nitrates equaled 44.0 percent of this, or 3.78 percent of the sample as it was gathered, showing that the surface soil is now very rich in nitrates. Sample No. 1061 is an actual sample of this soil taken to a depth of from four to six inches; the sample is a composite one from ten different points in the field. We see that it contains practically 1.5 percent of the water-soluble salts of which 13.0 percent was sodic nitrate which gives us 3,900 pounds of nitrates in the top six inches of the soil. This land lies on and above the wash alluded to which is eleven feet ten inches deep and is actually encroaching upon this land on both the north and west sides, which ought to secure excellent drainage especially as the land is not a heavy adobe soil, still it will puddle and retain water more persistently than one would think. The presence of the nitric acid in the first sample of soil, No. 815, taken at the base of one of these trees was a surprise to me, though I knew of its occurrence in adjoining portions of the land where the trees had already died. This whole section of trees, probably ten acres, has been dug up.

It is useless to attempt to present to oneself any questions in regard to what would have been the condition of this orchard and land had it not been drained, as it was a little over ten years ago. I am satisfied that the drainage system carries off the excessive water whether it is from the irrigation applied or from other sources and establishes a zone and certain areas where there is a comparatively uniform and moderate, but still an abundant supply of moisture which renders possible the development of the nitrates, if other conditions are favorable. What the optimum degree of moisture may be I do not know but my observation leads me to believe that a constant supply amounting, near the surface, to 18 or 20 percent, is sufficient for a rapid development of the trouble. After this is thoroughly established it seems to modify the moisture conditions of the soil as has been indicated by direct assertion of this fact and further by describing the ground as a veritable mud.

Orchard No. 14 is also a large orchard, but has quite a different soil. The burning has been very general and serious, at least twenty acres being involved, some of it on rather high and sloping land, some of it on lower and level land. The developments in this orchard during the season of 1910 were sufficient to cause the manager and the owners the gravest anxiety, while the developments in the past month, May, 1911, are extremely serious.

In this case we probably have an illustration of the effect of the irrigating water washing the nitrates down into the feeding area of the roots, and thus causing the damage, for some of the soil, while it is stained brown, is not at all in a bad condition. The former manager of this property kept the orchard well cultivated and the soil was in fine condition throughout the season of

1910, so that there was no good opportunity to observe the formation of crusts and mealy portions. The irrigating furrows, however, showed the brown lines very strongly in places. A sample of the soil taken from the northeastern section of the orchard to a depth of one foot showed only 0.062 percent of the matter soluble in water, but this soluble portion reacted like a pure nitrate solution. The trees were burning in this section of the orchard at the time the sample was taken. I had known for several years that a small part, possibly one-quarter of an acre, of this orchard, close to a deep wash, was affected with this trouble, but in the early part of June, 1910, I found the trouble more general and it grew quite rapidly in severity and extent till there was scarcely a tree in a large portion of the orchard but that showed more or less burning, and the present outlook is very bad.

ANALYSES	LI Water-Soluble Laboratory No. 1063 March 28, 1811 Percent	LII Water-Soluble Laboratory No. 1072 May 2, 1911 Percent
Calcic sulfate	10.388	31.808
Calcic chlorid	36.807	12.813
Magnesic chlorid	5.312	14.940
Magnesic nitrate	9.946	———
Potassic chlorid	———	2.329
Potassic nitrate	1.727	———
Sodic chlorid	———	1.983
Sodic nitrate	35.560	35.556
Iron and Aluminic oxid	0.066	0.267
Silicic acid	0.194	0.304
	100.000	100.000

Sample No. 1063 was taken in March and No. 1072 in May, 1911, from the southwestern section of the orchard. The total area of this orchard is ninety acres. A few trees died in this section of the orchard in 1910 but the death rate in May, 1911, is most alarming. Many trees that leafed out fully in the early part of the month, May, 1911, were killed outright by the 30th, as many as six or eight consecutive trees in a row, all succumbing in exactly the same manner. The water plane of the lowest portion of this land was at this time four and three-quarters feet below the surface. I wish to emphasize the following two facts; first, that apple trees in our country do not root deeper than two and a half feet as a rule; second, that it is very improbable that even the oldest reader of this bulletin has ever seen anything in any way comparable to the facts here presented, and I am fully convinced that they are so entirely beyond his observation and knowledge that he can neither conceive of nor justly pass judgment upon them for he does not know the facts.

I have at all times avoided anything approaching a dissertation

upon the facts believing that no statement of them can be more forceful than the facts themselves, but men who may have seen many things and never seen the like of this and others also judge such things to be impossible because they have not seen them and no one has, heretofore, described anything comparable to them. In these facts lies my only justification for the following statement relative to this case. Some five or six years ago I found in the southeast corner of this orchard a few dead trees, killed, as I then believed, by nitre. The ground was mealy and had that softness under the foot which we have learned to be peculiar to the earlier stages of this condition and sometimes persistent throughout the course of its development, even to the utter ruination of the land. No further trouble seemed to develop in this orchard for several years except that this bad area extended slowly from year to year. I visited this orchard but once or twice in 1909, and if there was any general burning of the orchard I neither saw it nor was it called to my attention. That there was some burning is understood, especially in the southeastern section. In 1910, however, the burning was very general throughout the ninety acres. A portion of the orchard was decidedly bad and many trees, the actual number I do not know, died and were removed.

In the northeastern section of the orchard many trees that so far as was known, were in good condition in 1909, were in bad condition and the leaves were burning in July, 1910. Even I had difficulty in pursuading myself that much of the injury was not due to freezing dry. The fact remains, however, that the leaves were burning in just the manner that nitre burns them; further, the sides and crests of the irrigating furrows were streaked with brown, which we have learned to be an almost infallible sign of the presence of nitrates. Holes were dug in this section of the orchard without striking water but the trees were being injured. In the spring of 1911 a party kindly bored a hole at my suggestion to determine the depth of the water plane; he found the soil dry at a depth of six and a half feet. At the time of my last visit to this orchard, May 30, 1911, the trees at this point had not yet begun to burn. The leaves were large and deep green in color. One would infer from the conditions as they presented themselves that too little water had been applied to this section. I have no contour map of this orchard but this northeastern section is patently the highest portion of it and the slope is to the south. A little way down in the orchard we found the leaves of the water sprouts burning to such an extent that there could be no possible question concerning the cause. This season, 1911, is the first time that I have seen burning to any noticeable extent before the middle of June, but this year it is very common at this date, May 30.

In 1910 almost every tree throughout the central portion of

PLATE II.—See page 41.

No. 1 is the upper figure

this orchard showed in August and September more or less burning and here and there a tree wholly succumbed. Many trees, however, were only severely injured, either by having one or more limbs entirely killed or the extremities of the branches killed back varying distances. As yet this section of the orchard does not show the burning badly at all; it is too early and the trees have not had a liberal supply of water.

The western part of this orchard was rather bad, and many trees showed burning last year, but the burning did not take place till the latter part of the season, from mid-summer till autumn. This year, however, many trees that came into full leaf in early May had already been killed by the thirtieth of the month. I visited this orchard on the second and again on the thirtieth of this month and while I have seen other orchards destroyed quickly I have nowhere seen anything surpassing this in the extent of the injury and the rate of its accomplishment. The ground water was four and three-quarters feet below the surface. The surface soil was dry but brown and mealy. The disc had cut about three inches deep and the sides and bottom of the cut looked as though crude oil had been uniformly distributed over them. Sample No. 1063 was gathered from the surface of this ground on March 28, and was taken to a depth of two or more inches. It was a composite sample made up of smaller samples from several places. Sample 1072 was likewise a composite sample taken from the sides and bottom of the cut made by the disc. These samples represent the salts soluble in water and contained in the top two inches of the soil, where the trees are now dying very rapidly, and we see that they agree in showing 6.158 and 6.197 percent of such salts, 47.233 percent of the former and 35.556 percent of the latter being composed of nitrates. Calculating the nitrates present in the top two inches of this soil, we obtain 9.6 tons per acre for the sample taken in March from the surface soil and 7.6 tons for the sample taken in May from the sides and bottom of the disc cuts or furrows, or calculated on the acre-foot, 58 and 44 tons respectively. The ground where the samples were taken is lower than a portion of the orchard but the ground is still so sloping that we cannot explain the presence of this large quantity of nitrates by supposing them to represent the washings from the rest of the orchard.

Plate II shows the condition of some of the trees in this orchard on June 23, 1911. The upper photograph, Fig. 1, represents a tree which at this time showed no effects of the nitrates. The lower one, Fig. 2, represents a tree which developed a full foliage in May and was dead at the time the photograph was taken, June 23, 1911. These two trees do not stand more than fifty or sixty feet from one another. The only reason why trees even

this far apart, were chosen was because we could not get a good view of an unaffected tree standing in the next row and contiguous to the dead tree represented by the lower photograph.

In a preceding paragraph I stated that on May 30, 1911 the trees were burning badly in the southwestern portion of the orchard, as many as six or eight consecutive trees in a row being attacked and dying in the same manner. On June 23 I counted thirty-five consecutive trees in one row which were all attacked to a greater or less extent. Of these thirty-five trees not less than twenty-five were already dead and of the remaining ten five were already so badly injured that there was no hope of their recovery.

Case No. 15—Under this number I shall present two adjacent orchards, without going into any details. I first noticed one of these orchards about four years ago. At that time about one and a half acres of the land was bare; the few trees that were still standing were dead. The surface of the soil was brown. I visited this orchard in 1909 and took a sample of the soil to a depth of one foot. The condition of the land did not appear to be very bad but it had been recently cultivated which operation effectually conceals this condition if carefully done. This sample yielded 3.580 percent of water-soluble which afforded the following results:

ANALYSIS LIII

	Water-Soluble Laboratory No. 779
	Percent
Calcic sulfate	30.528
Magnesic sulfate	19.901
Potassic sulfate	1.878
Sodic sulfate	23.006
Sodic chlorid	12.951
Sodic nitrate	18.307
Manganic oxid	0.267
Silicic acid	0.162
	100.000

This analysis indicates the presence of a little more than 13 tons of sodic nitrate to the acre-foot.

There is another orchard immediately to the north and east of this to which my attention was directed in the spring of 1911. Drains were laid in this land in the autumn of 1910 with the idea of washing the soil by heavy irrigation and depending upon the drains to carry off the leachings of the soil with the excessive water which might be added or which might possibly accumulate from other sources. The soil is a sandy loam passing into a clayey loam in places. The water plane, determined by means of a series of wells, was four and a half feet below the surface. Some of the

trees at this time, May 1, 1911, were burning quite badly though the leaves were not yet fully developed. It is unusual to observe this burning of the leaves in any degree so early in the season and very much more so to meet with such marked cases of it as these trees presented. Unfortunately I do not know how high the water plane rose during the season of 1910, but information elicited by specific inquiry in regard to this point did not suggest an undue amount of water as the cause of the trouble or as the probable source of the nitrates. I visited this orchard again on May 30, 1911, at which time the destruction of the orchard not only seemed a certainty but was already far advanced. The following analyses represent the surface soil and the water from a well located near by a burning tree. This sample of water was sent by the owner.

ANALYSES	LIV Water-Soluble Laboratory No. 1073 March 28, 1911 Percent	LV Water Residue Laboratory No. 1200 May 12, 1911 Percent
Calcic sulfate	24.275	36.596
Calcic chlorid	8.658	———
Magnesic sulfate	———	2.194
Magnesic chlorid	8.577	11.654
Potassic chlorid	1.951	2.107
Sodic carbonate	———	5.040
Sodic chlorid	39.187	41.992
Sodic nitrate	17.075	Minute trace
Iron and Aluminic oxid	0.088	0.078
Silicic acid	0.189	———
	100.000	100.000

Sample No. 1073 represents the surface soil, an inch and a half or at most two inches deep, taken beneath a tree which was already burning. This sample yielded 5.768 percent of salts to water, of which a little over 17.00 percent, 17.075, was nitrates, giving us 6,500 pounds, three and a quarter tons, of nitrates in the top two inches of this soil per acre. Sample No. 1200 is the ground water taken from a well near to another burning tree which has since died. This water contained 10,094 p. p. m. of total solids, but contained so little nitric acid that five grams of the residue gave with hydric and ferrous chlorids only a minute trace of nitric oxid. This test, like all of the nitric acid determinations, was done in duplicate. It is a striking fact that this ground water within four and a half feet of the surface on which an abundance of nitrates occur should be so nearly destitute of even a trace of nitric acid, but this is the second case; we have already given one case in which this is so and we have still another which will indicate the same thing. In the case of sample 1201, a drain water, we have given even fuller data, showing the presence of 8,489 parts of salts per million with only 0.018 p. p. m. of ammonia, 0.00003

p. p. m. nitrogen as nitrites and 0.1 p. p. m. of nitrogen as nitrates, which could scarcely be possible if the surface salts were washed down into this ground water to any extent, and contrariwise all of these samples agree in leading us to most extremely improbable conclusions if we consider them to be the source of the nitrates. While this is not yet an extreme case the results are most striking and most evidently false, for if this ground water were the source of the nitrates and it were as rich as this drain water we would have to assert that 40,122 acre-feet of it had been evaporated to dryness on each acre of this orchard which would mean a mass of water 7.5 miles deep. This amount of water would deposit 541,670.6 tons of salt on each acre of which only 3.25 tons, the amount now present in the top two inches of this soil, would be nitrates, and the time required to effect this, assuming the evaporation to take place from a free water surface at the rate of five feet per annum, would be 48,128 years. The facts, on the contrary, are that these apple trees grew healthily for ten years or more until within the last two or three years which is conclusive proof that these nitrates were not present previous to this time, say three years ago, in sufficient quantities to do any damage, but within this time the limit of tolerance has been passed and this orchard has been destroyed.

It is evident from the results in all the cases of ground waters given that it is not water derived from the surface of the land which has passed through the soil and now forms a sheet of water beneath this soil but probably represents, in large measure, the leakage from the irrigating ditches and other similar sources, for we have already given samples of such waters as have without any reasonable doubt come from the soil, i. e., passed through the soil of nitrate areas, and they are rich in nitrates. Further, this ground water, especially the drain water previously given owes its immediate origin to the gravel which underlies the sand, and which, as elsewhere stated, constitutes the natural drainage of this section. I do not know whether the section where the well is located is underlaid by gravel or not, but the water agrees with the others here given in containing so good as no nitrates. Another point is the absence of ammonia and nitrites from this drain water, which can only be interpreted as indicating that no reduction of nitrates can have taken place in the areas from which this water came. The reader is referred to Analysis IX, Colorado Experiment Station Bulletin 155, pp. 12 and 13, for the description and composition of a water derived from a nitre soil. We cannot extend the consideration of this subject at this time.

Case No. 16—Orchard No. 3, described in Bulletin 155, pp. 16-18, has grown worse and many trees, not previously described,

have shown burning to a very serious extent. A little to the east of this place is a piece of ground which some one has tried to bring under cultivation. The piece of land is not very large and lies between two ridges and beside the public road. An open drain was run north and south through the center of it, from the north end of which another open drain was run parallel to an irrigating ditch across the north and northeast end of the east half, to intercept leakage from the ditch. These ditches were not well cared for and their efficiency was greatly reduced owing to the indifference of the owner. A large irrigating canal runs on the east side of the public road and is six or more feet below it, while this piece of land lies on the west side of the road.

The west half of this land was planted to oats last spring, 1910. The condition of the field on September 13, is shown in the upper figures, Plates III and IV. That of Plate IV shows the oats that survived. The photograph conveys a good idea of the size and sharp delimitation of the piece, also of the rank growth made by the plants, they being well above the waist of a medium sized person. The photograph, however, does not convey any idea of the extremely dark green color of the plants. The other figure, Plate III, shows the condition of the rest of the field, the western portion, and the irrigating creases, also that the land was entirely bare, there being only a very few Russian thistles that had survived. These photographs show in a most excellent manner the brown stained margins on the spaces between the creases, even the slight encrusting and puffed up condition which is very characteristic of extreme cases of this trouble, can be recognized in Plate III. These pictures show that the ground immediately back of this, north of it, is higher and some of it is uncultivated, while other portions of it support old and healthy orchards. The pictures also convey a fairly good idea of the length of the field, as the public road runs only a few feet, perhaps thirty, this side of the picture. The length may be four hundred feet. I did not measure it but I think that it cannot be more than this. The north and south ditch runs a little to the east of Plate IV, and the irrigating ditch at least six feet deeper than the lower end of this field runs within forty or fifty feet of its south side. I have already given too many details relative to this piece of ground. The growth of the oats on ground which is neither higher nor lower, neither wetter nor drier than the rest, indicates that it is really not a question of seepage and drainage. This ground was not very wet at any time that I have seen it. It was wet enough to justify the ditching, and the results have been disappointingly small. I interpret this as being in harmony with many other observations, that while this land would be considered as seeped land the chief difficulty is not the water but the bacterial flora of the soil.

A sample of the surface soil was taken from that portion of the field represented in Plate III immediately in front of the person who is actually holding the sample. This sample was taken only to a very shallow depth, scarcely more than one inch; it yielded to water 8.83 percent after being thoroughly well air-dried.

ANALYSIS

	LVI Water-Soluble Laboratory No. 1012
	Percent
Calcic sulfate	5.941
Calcic chlorid	26.566
Magnesic chlorid	4.469
Magnesic nitrate	21.527
Potassic nitrate	4.107
Sodic nitrate	37.269
Silicic acid	0.121
	100.000

Case No. 17—The trouble in this orchard came to my notice for the first time in July, 1910. Inquiry elicited no satisfactory information relative to the presence of any burning of the leaves during the preceding year. I, however, became fully convinced of one thing, namely, that while it is very probable that the trouble was present in 1909, even to the extent of killing a few trees, it was not so general as it became during the early part of the season of 1910. The location of this orchard is very favorable; the soil is of the best quality and the drainage is excellent. The red mesa-soil is uniform in appearance and texture for a depth of four and a half feet, when it changes to a gravel as shown by a hole dug by a badly burnt tree. The land had been irrigated probably a week prior to the date on which I dug this hole and took my samples. We found, however, no excess of water in the soil. The irrigating water, if it had at any time made a portion of the soil excessively wet, had already drained out to such an extent that the soil was no more than in good condition, even the foot of soil next to the gravel was not excessively wet, perhaps between twenty and twenty-five percent of its weight being water. This orchard consisted of a younger and an older part. The burning was in most cases very moderate, so moderate that one would be surprised if the result should be fatal unless the soil conditions should grow worse. A few trees had already died from this cause, though there were other dead trees with girdled crowns to which their death was probably attributable. There is no question of seepage involved in this case, but there is a good supply of irrigating water and a small ditch flowing just west of the orchard. The prevalence of this trouble throughout this orchard and the intensity of the burning on a few trees were matters of surprise to me. I had known of the

occurrence of nitrates in very large quantities in this section for two years, but this and some others were new and wholly unexpected occurrences. I took two samples of soil, one to a depth of three inches, No. 977, the other from the fourth to the fifteenth inch inclusive, No. 978. The water-soluble in No. 977 equalled 2.92, in No. 978, 0.54 percent.

ANALYSES	LVII Water-Soluble Laboratory No. 977 Percent	LVIII Water-Soluble Laboratory No. 978 Percent
Calcic sulfate	40.376	50.910
Magnesic sulfate	22.470	15.972
Potassic sulfate	3.686	8.639
Sodic sulfate	3.606	16.814
Sodic chlorid	23.930	6.039
Sodic nitrate	4.902	Trace
Iron and Aluminic oxid	0.196	0.288
Silicic acid	0.834	1.338
	100.000	100.000

Sample No. 977 gives us 65.5 pounds of nitrates available to each such tree as this, assuming that the roots occupy a circle of ground forty feet in diameter and that the whole of the nitrates in the top three inches, is by any means brought within the feeding area of the roots.

As I have elsewhere stated I do not know how small a quantity of nitrates will suffice to produce a burning of the leaves. The tree in question was burned, but scarcely enough to produce serious injury. Our observations would have to be continued into, if not through, the season of 1911 to form any reliable judgment in regard to this point.

This land is so located that it is difficult to believe that these nitrates could have been washed from any adjoining lands, and if they were brought to the surface by capillary attraction they must have existed in the soil itself, but our analysis of the soil taken from the fourth to the fifteenth inch inclusive shows only a trace of nitrates in the aqueous extract. It is also out of the question to think that the irrigating water, snow water, might contain enough nitrate to permit of such a concentration as we find even in this case. These points are mentioned in this connection because in many cases the conditions legitimately admit the question of transportation from higher lands either by seepage or washing. That is, they could fairly be raised whether they actually apply or not. A case in point, i. e., Case 8, has been presented in considerable detail to enable the reader to judge for himself whether washings from the higher lands or the seepage from them could possibly account for the nitrates occurring in the land described. The presentation of the analyses given is itself a proof that I have most seriously

considered these possibilities, but I have failed to see how these theories of accounting for the presence of nitrates, never before met with in arable soils in such quantities and over such large areas, so far as I know, apply to these cases and especially to Case 8, which, as is stated in the presentation of it, is of all the cases discussed probably the one most favorable for the application of these usual explanations.

This is by no means the only instance of the occurrence of nitrates in this immediate neighborhood but it is the best example of the general effects of the nitrates in ground that we would usually consider almost entirely free from any objection that I can recall. There are very much more severe cases of this trouble in the neighborhood but the land is not so well located for orchard culture. One of the most striking cases in point was a five-or eight-acre orchard planted on ground that sloped toward a slight depression. A deep drain ran at the base of the slope and two lines of underdrain, six feet deep, extended up into the orchard. We dug a hole three and a half feet deep at a point which I thought a favorable one to find water but I found none. At three and a half feet we encountered a stratum of marl and below this there is, as shown by the ditch and drains referred to, a coarse gravel with some marl. The surface of this ground was very brown and mealy. The trees on July 18, 1910, were burning very badly and many of them were already dead. The owner stated that they began to die during the season of 1909, but I did not learn whether the trouble began in the spring or summer.

A number of other instances of trees similarly located could be mentioned. In some section of our orchard districts it is difficult to find an orchard which does not show more or less of the trouble at some time during the season. The trees that are at all seriously affected seem to have no recuperative power.

Case No. 18— This case, like several others, presents more than an orchard, but as an orchard is actually involved I have retained the designation. This is quite fully justified not only because a part of the land is set to apple trees but also because they present a marked case of this trouble. The case is an involved one; in part of the land there is an excess of water, in other portions the soil is shallow, a stratum of marl coming near to the surface, but in other portions the conditions are good, or fairly so. It is exclusively of the better part of the orchard that I shall write. The trees were twelve years old the first time that I saw them, now going on three years ago, and so far as I have been able to learn they had not at that time shown any of this trouble, though I took a sample of soil on my first visit to the orchard in order to test it for nitric acid. This sample contained 2.126 percent

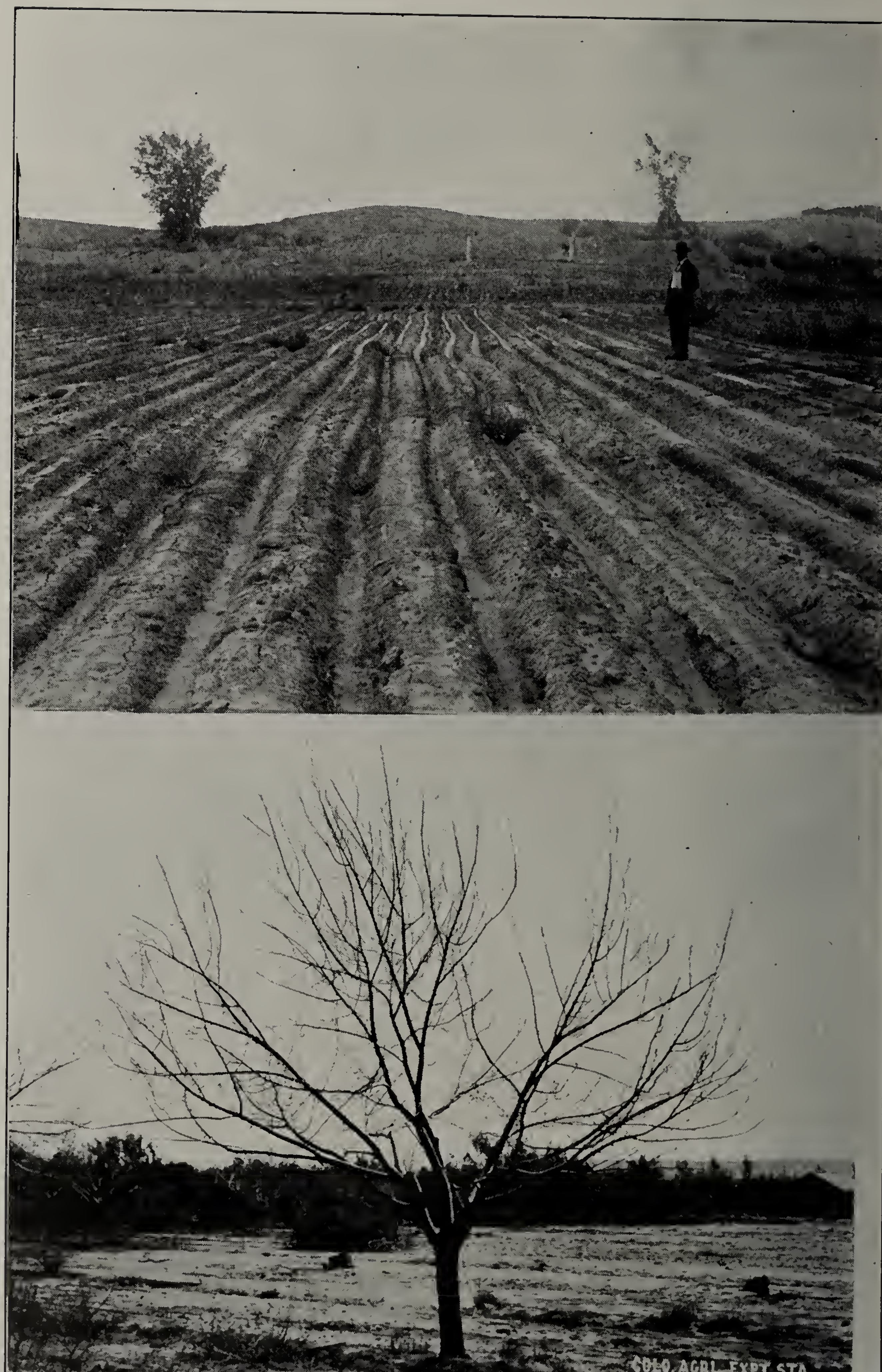

PLATE III.—See pages 45, 62 and 63.
No. 1 is the upper figure

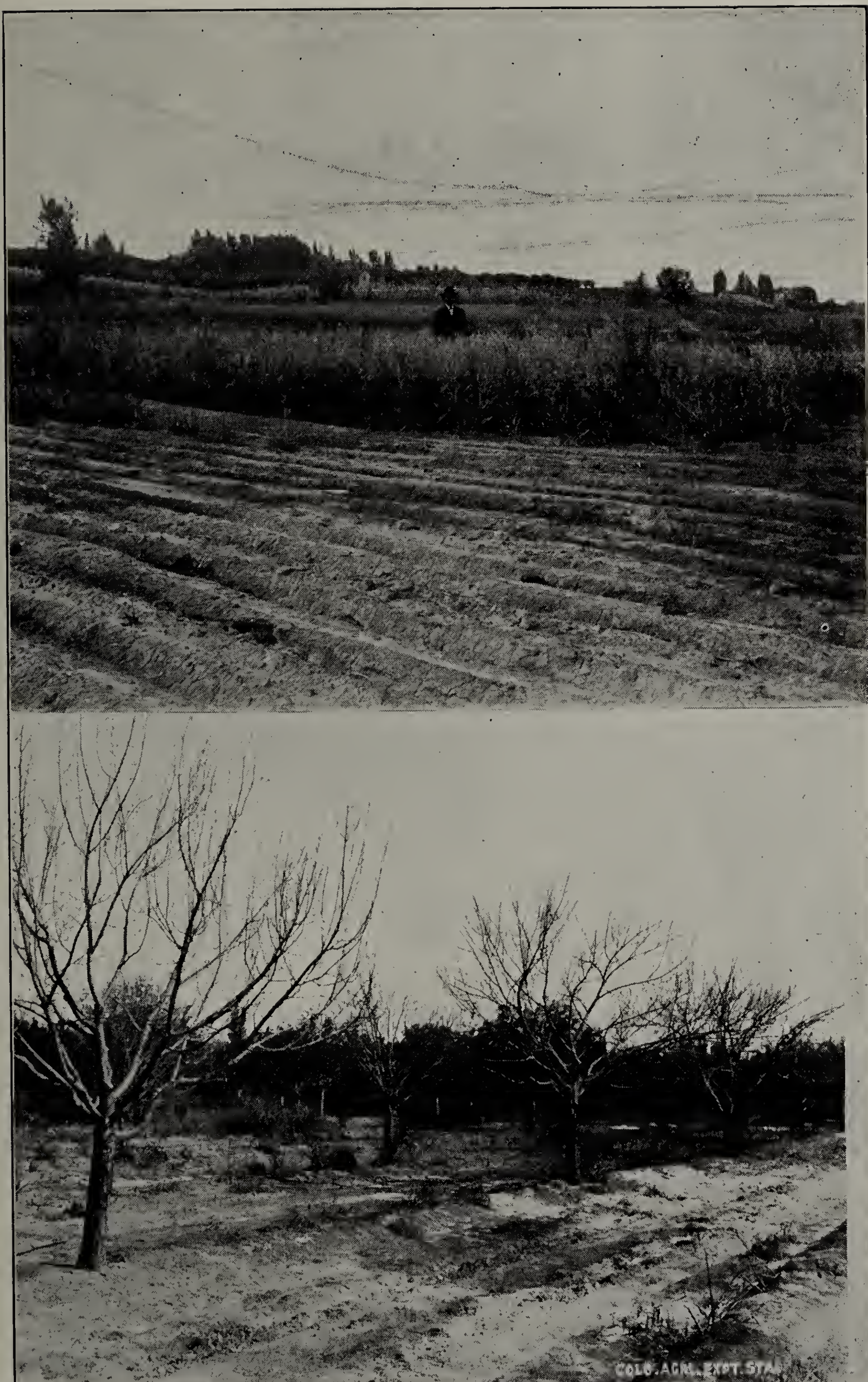

PLATE IV.—See pages 45, 63 and 67.

No. 1 is the upper figure

soluble in water and reacted strongly for nitric acid. The reaction depended on in all cases is that with ferrous sulfate and sulfuric acid. If a few grams of soil, from 10 to 25, will not give with 20 to 30 cc. of water, a solution which will give a decided reaction with these reagents it scarcely belongs to the class of soils, with which we are concerned. The owner put in a short drain to protect a portion of his orchard which he feared might be suffering on account of excessive water. This drain never collected much water, and was entirely dry on my next visit. The trees in this part of the orchard were at this time, July 23, 1910, burning badly.

We had in this orchard an excellent opportunity to compare the nitre burning with spray burning. The two differ in the point of attack, the nitre beginning at the apex and the margins of the leaf and very rarely, if ever, on the inner parts of the blade, and the color is lighter.

This is a piece of sloping ground and is at the base of a hill. There is no irrigation above it that I can recall. A little to the south and west of this orchard on the roadside is one of the most remarkable spots of this character that I have met with, not excepting the first one that I recognized and which is represented by Analysis No. 1, Bulletin 155, page 7.

These spots, for there are a number of them, are scarcely worse than some of the land in the orchard where the trees were burning very badly. This soil is actually kept moist by the deliquescent nature of the salts formed. A sample from such a spot in the orchard gave 12.10 percent soluble in water and the notes state that this residue had to be dried at 110° in the air-bath for 12 hours. Another sample gave 12.560 percent soluble in water, and this extract bears a special label "had to dry at 115° for 20 hours to get dry enough to put into the bottle." I am giving these details perhaps *ad nauseum,* but I find that they appear so strange to persons who have never met with such facts themselves as to seem wholly incredible. The analyses of these samples may be their own witnesses.

ANALYSES	LIX Water-Soluble Laboratory No. 791 May 10, 1909 Percent	LX Water-Soluble Laboratory No. 823 July 23, 1909 Percent	LXI Water-Soluble Laboratory No. 790 May 10, 1909 Percent	LXII Water-Soluble Laboratory No. 828 Percent
Calcic sulfate	55.242	21.249	14.495	4.401
Calcic chlorid	———	———	47.523	28.313
Magnesic sulfate	15.021	14.253	———	———
Magnesic chlorid	11.883	———	4.363	18.801
Magnesic nitrate	———	———	10.792	0.491
Potassic sulfate	———	1.606	———	———
Potassic chlorid	3.005	———	2.114	———
Potassic nitrate	10.001	———	———	2.711
Sodic sulfate	———	35.798	———	———
Sodic chlorid	———	10.607	———	———
Sodic nitrate	4.273	16.395	20.585	45.283
Iron and Aluminic oxid	0.139	———	———	———
Silicic acid	0.436	0.092	0.128	———
	100.000	100.000	100.000	100.000

ANALYSIS	LXIII Soil Laboratory No. 791* May 10, 1909 Percent
Sand	67.910
Silica (sol.)	3.280
Sulfuric acid	0.760
Chlorin	0.200
Phosphoric acid	0.170
Carbonic acid	2.640
Lime	4.250
Magnesia	2.060
Sodic oxid	0.530
Potassic oxid	0.880
Ferric oxid	3.900
Aluminic oxid	4.400
Manganic oxid (br.)	0.280
Moisture, 110°	3.510
Ignition	5.640
Sum	100.410
Oxygen equiv. to chlorin	0.050
Total	100.360
Humus	0.380
Humus ash	0.382

This is an extremely interesting instance of the occurrence of nitrates. The ground slopes toward a meadow, a part of which has been converted into a reservoir but the land is decidedly higher than the meadow, as it is on the lower slope of a hill. The field along the roadside where one of these spots occurs was in alfalfa; the land was good, and the alfalfa healthy, so that one seems

*The depth to which this sample was taken is not stated. It was probably about three, certainly not more than four, inches.

justified in assuming that no considerable rise in the water table has taken place for a number of years, and further that it is reasonably low.

The ordinary soil analysis shows nothing which we might interpret as indicative of any deficiency or trouble.

Case No. 19—While this number is used to designate a specific locality, it will embrace a number of minor occurrences within a stretch of country about five miles long, lying approximately one hundred and fifty feet above the river bottom. Portions of this mesa are seeped and a drainage system has been put in, with what results I am not able to state, but it is claimed that it has been of benefit.

This section was scarcely more than referred to in Bulletin 155, as only two analyses, one of an alkali, Laboratory No. 595, and the other of the water-soluble portion of a soil, Laboratory No. 588, were given with a very meagre statement of the conditions. These samples were taken in 1907. It is true that attempts have been made to drain the land since that time, and the water conditions have doubtlessly been ameliorated, but this nitrate condition has, in my judgment, become more intense, for in 1909 and 1910 there were many patches of nitrates which could not escape the attention of anyone, and which were not present in 1907; besides, the analyses of samples taken in 1907 are by no means so rich in nitric acid as the samples gathered in 1909 and 1910.

There are many points in regard to which my information is not satisfactory, for instance, it is almost impossible, at this time, to obtain reliable data relative to conditions only a few years ago. The properties have changed hands and the present owners will very often make positive statements about conditions which cannot be substantiated. The fact is that they are so averse to acknowledging ignorance of these things that they prefer to give you such statements as it pleases them to make. The owner of the land which is, perhaps, becoming worse each succeeding year does not like to rehearse his misfortunes, especially if he suspects that you may be a prospective buyer of his or other property in the neighborhood. Many of them feel that it is disloyalty to their community to acknowledge patent facts. This trait, in their judgment, and in that of many others, may be wholly praiseworthy, but it hinders greatly in a study of this sort in which one has, in a measure, to depend upon the testimony of the residents for many facts in the recent history of a section. That there was a period of greater prosperity for this section is attested by the remnants of orchards, fields which a few years ago were productive, abandoned houses now falling into decay, etc. These witnesses to the very poor judgment of former occupants or to a period of better

conditions, are usually dependable, but we must determine which of the two it is.

I believe that there is no doubt but that the settlers of this section suffered many disappointments and that while events showed that they misjudged the difficulties, they had at the time no way of recognizing these difficulties, or of knowing how serious they were. In portions of this section the water plane in 1889 was, according to the information that I have been able to obtain, twelve feet below the surface. In October, 1907, I found it four feet below the surface. How much it had been recently affected by the irrigation of neighboring lands I do not know. Here is a difference of eight feet in the height of the water plane, and why this water did not drain out was not apparent. In 1907 a very considerable area of this land was seeped and there was some nitrate present but not enough to become an easily recognized feature. Drainage has since that date been introduced on a considerable scale and in 1909 and 1910 nitre spots were recognizable in many places. I wish at the present time simply to record the sequence of facts. I will first consider a piece of land, a part of which had been planted to barley and a part to oats. The whole piece measured several acres. Both the barley and oats had been creased for irrigation after sowing. In very many places there were no oat or barley plants between the creases. The seed had never come up, or the young plants had been killed. There were abundant indications that the latter had been the case, whether the former had been or not, but from my observations on other areas I have no doubt but that it, too, was the case here, i. e., that much of the seed did not come up. The plants were confined to the sides of the creases just above the edge of the water. The bottom of the crease or furrow was, of course, free from plants, and the crown between the creases was brown and barren and extremely mealy.

The question of where the water which had raised the water table in the years between 1889 and 1907, eight feet, came from is appropos. So far as I know this rise was wholly due to the irrigation of these lands, in other words, this section does not receive the drainage from other lands higher than it.

I did not attempt to take a sample of this soil, only one of the mealy surface portion. The sample, 981, was taken with an irrigating shovel and I probably took some of the soil as deep as two inches. This sample as taken contained 28.44 percent of its weight, air-dried, which was soluble in water. It is no wonder that the oats and barley died. This is so great an excess of salts that one is tempted to ask whether sodic sulfate or any other relatively innocuous salt would not have sufficed to account for the conditions presented. I will record the facts as I find them, here as elsewhere, without regard to the question of whether they appear

to be in harmony with my views or not. The quantity of soluble salts in this surface, mealy soil is exceptionally high and contains an unusually large amount of organic matter for our samples. In judging this amount and the effects of the salts in this sample it must be borne in mind that it was taken to represent the surface portion only and the fact that I possibly got some portion of the sample at a depth of two inches was an accident due to the fact that I took it with a round-pointed shovel. The great bulk of the sample was made up of the mealy, almost dry, surface portion. This did not form an incrustation of effloresced salts, as we often find where the common white alkali prevails. Professor Sackett tells me that the soil extract made from the surface sample which he took failed to develop azotobacter in his culture medium. They had probably been killed as well as the other plants due to the concentration of the salts. This is not the only sample in which this has been found to be the case. In the case of Orchard No. 2, Bulletin 155, pages 13 to 17, we found this to be true. Samples from the surface of excessively bad portions gave no development of azotobacter, whereas samples from below the surface or at or near the edge of the bad territory gave a very abundant development. It is therefore, quite what might be expected, i. e., to find this ground, so extremely rich in soluble salts, devoidof azotobacter.

The following samples are from the same section of country but not from the same place. No. 590 and 595 are from the same place but 981 is from another, a mile or possibly more north of it. I used the term spots in describing these occurrences in Bulletin 155 and again spoke of the nitrates occurring in almost continuous but irregular areas, but have not deemed it necessary to give analyses of alkalis and soils outside of these areas except in Case 8, as the amount of the nitrates are so unusual that I have deemed it unnecessary. Samples 590 and 595 are from the same piece of land and taken not far from each other on the same date. They were both originally taken as samples of alkalis, as we were studying, at that time, the effects of alkalis and the maximum amount of them compatible with good crops, etc.

The water-soluble equalled in 590, 7.57, in 595, 33.33 and in 981, 28.44 percent. Samples 590 and 595 were collected in 1907 and 981 in 1910.

ANALYSES	LXIV	LXV	LXVI
	Water-Soluble Laboratory No. 590	Water-Soluble Laboratory No. 595	Water-Soluble Laboratory No. 981
	Percent	Percent	Percent
Calcic sulfate	19.561	9.102	3.651
Magnesic sulfate	11.236	8.076	3.558
Potassic sulfate	1.039	———	1.034
Sodic sulfate	52.457	56.254	70.746
Sodic chlorid	10.827	22.609	16.109
Sodic nitrate	Trace	2.771	4.854
Sodic silicate	0.247	0.308	———
Silicic acid	———	———	0.048
Loss	(4.633)	0.880	———
	100.000	100.000	100.000

Another sample of soil, 826, taken about one mile and a half south of No. 981, and a year previous, is interesting because the occurrence was a new one at the time. It was on the face of a low bank where they had plowed and scraped out dirt in working the road. I am quite familiar with this road as it is a section in which I have observed the alkali question for going on five years, and I feel quite safe in making the statement that the occurrence was one which had appeared there within a few months, certainly within a single season. I do not know how deep the water table was at this place but the land was so high that seepage would not ordinarily be thought of; in this case, however, the presence of so large an amount of soluble salts, 16.30 percent, will appear to some as indicative of a seeped conditon. In this connection I repeat again the observation that I have not yet found this condition in places where the water table is near the surface of the ground, especially if it is permanently near the surface, but in such places as have an abundant, but not an excessive, water supply. I do not pretend to know all the conditions which are necessary to determine the development of these nitrates, but that water is one of the conditions is very evident. For in ground that is in good condition, with which, ordinarily speaking, no fault can justly be found they, the azotobacter, will develop along the margins of irrigating furrows; again, they are apt to develop near a ditch, even on level ground, and are especially liable to appear on the outside of a ditch bank where the apparently flourish.

Under the caption of Case No. 8, I have given, it appears to me, conclusive proof that neither the alkali, nor the soil, nor yet the ground water contained any nitrates, still the outside of a ditch bank running beside this land, practically running through it, is almost or quite black in color, which color is continuous for considerable distances, and the surface soil is decidedly rich in nitrates. This color is not due to the wetness of the soil, nor to the alkalis, including calcic and sodic chlorid, in the usual use of

this term but to the presence of azotobacter and nitrates which do not come from the adjacent land or the ground water, nor from the water that flows in the ditch, but are developed in the soil, and the controlling factor in this case is the constant and abundant supply of moisture. To some the facts given may not be fully convincing that the nitrates are formed *in situ*—to me they are, but we will give, in the proper place, further proof that this is so. This is true, too, of the sample which we are discussing; the ground is not seeped but there is a ditch perhaps ten feet away which probably furnishes the necessary moisture. I do not know why this had not developed in this place prior to 1909, but it was there in 1909 and I had not seen it there before. This and the next following samples were taken during a shower and I have made no notes of how the samples were taken. They may have been, and probably were, shoveled up hastily as it was not a good time for making notes. The samples were taken to learn the character of these surface salts. This accounts for the high content in water-soluble which amounts in No. 826 to 16.30 percent, and in No. 822 to 32.07 percent. The latter sample, No. 822, was taken a mile or more south of sample No. 826 and near to the edge of an alfalfa field which was in good condition at the time, and so far as I know is at this time. There was, however, a depression immediately south of this which is, at times, filled with water.

ANALYSES	LXVII Water-Soluble Laboratory No. 826 Percent	LXVIII Water-Soluble Laboratory No. 822 Percent
Calcic sulfate	16.044	7.973
Magnesic sulfate	8.411	7.911
Potassic sulfate	1.074	0.999
Sodic sulfate	49.623	73.105
Sodic chlorid	22.345	9.074
Sodic nitrate	2.394	0.839
Iron and Aluminic oxid	———	0.040
Silicate acid	0.109	0.059
	100.000	100.000

The territory from which the last five samples were gathered is above the shales which were described and analyses of which were given in Bulletin 155 pp. 28 and 29, Laboratory No. 645, and while this locality is not the one referred to in explaining the occurrence of nitrates in certain waters and in the shales themselves in which I state, "The occurrence of nitrates in the waters and apparently in the shales is susceptible of an easy explanation, i. e., the nitre spots which are only exaggerated instances of a general condition, occur in lands above the shales," it exemplifies the condition described in a most satisfactory manner.

The following analyses of a soil and its aqueous extract will

help to give a fuller view of the general state of affairs in this section. The soil was, of course, strongly impregnated with alkali, and judging from the age of the orchard that occupied it, had been under cultivation for a number of years, not less than fifteen, and probably more than twenty. The water-soluble equalled 6.65 percent of the air-dried soil.

ANALYSIS	LXIX Soil Laboratory No. 588 Percent
Sand	42.745
Silicic acid (sol.)	26.526
Sulfuric acid	3.187
Chlorin	1.799
Phosphoric acid	0.111
Carbonic acid	1.345
Lime	3.634
Magnesia	2.032
Sodic oxid	4.020
Potassic oxid	1.191
Ferric oxid	3.792
Aluminic oxid	5.483
Manganic oxid (br.)	0.113
Ignition	(4.428)
Sum	100.406
Oxygen equiv. to chlorin	0.406
Total	100.000

ANALYSIS	LXX Water-Soluble Laboratory No. 588 Percent
Calcic sulfate	22.550
Magnesic sulfate	7.381
Potassic sulfate	2.468
Sodic sulfate	36.168
Sodic chlorid	24.884
Sodic nitrate	6.297
Silicic acid	0.252
	100.000

It is difficult to see how the drain waters from such a section, abounding as this has during the past year in such spots, can fail to be comparatively rich in nitrates. Analyses of two drain waters, and two seepage water were given in Bulletin 155. The two seepage waters were from the base of another mesa, but in this general section of country; the two drain waters were from an entirely different section of the country but one where similar conditions prevailed. We are justified by these facts in assuming

PLATE V.—See pages 62 and 63.
No. 1 is the upper figure

that the seepage and drain water from this area contain nitrates enough to account for all the nitrates which we found in the shales which actually underlie this mesa.

Case No. 20— On page 19, Bulletin 155, I gave a very brief description of the conditions obtaining in the field where our Laboratory No. 680 was collected. I mention it again merely to give the salient features of its condition in 1910, a little over two years after that sample was taken. The land was described as having been an oat field in 1907; the surface was stated to be puffed up and mealy. A sample taken to a depth of two inches yielded 5.42 percent of water-soluble salts salts which contained nitric acid equivalent to 21.719 percent of sodic nitrate. This land was in very bad condition in 1909 and barren in 1910. Of the original 25 acres more than 15 acres (estimated) has been rendered valueless by the combined effects of the seepage and nitrates. What the seepage has not ruined the nitre has, with the exception of possibly ten acres or less. The following four samples were gathered in September, 1909. No. 837 was gathered from a portion of the field where the water had probably done no damage, but where there was much white alkali. The water-soluble equalled 12.96 percent of the air-dried sample. My field notes mention the fact that the brown spots appear on the outer or upper edge of the white alkali. This is a sample of such material as occurs in these mixed spots. No. 839 is a soil sample taken from beneath a brown spot after the surface portion had been removed. The sample represents six inches of soil, five to ten inches inclusive. The water-soluble equalled 12.67 percent. Nos. 841 and 842 are samples of the "black alkali" from different places in the field. The water-soluble equalled 10.30 and 10.40 percent respectively. This land, where these samples were taken, was still in pretty good condition in February, 1908, but in September, 1909, the land was already in bad condition, and in July, 1910 I have entered the note that this land was ruined. There still remained from five to seven acres of winter wheat which was very fine indeed. No samples were taken in July, 1910, because a very heavy rain had fallen only a few hours before my visit.

ANALYSES	LXXI	LXXII	LXXIII	LXXIV
	Water-Soluble Laboratory No. 837 Sept. 22, 1909	Water-Soluble Laboratory No. 839 Sept. 22, 1909	Water-Soluble Laboratory No. 841 Sept. 22, 1909	Water-Soluble Laboratory No. 842 Sept. 22, 1909
	Percent	Percent	Percent	Percent
Calcic sulfate	1.086	41.538	12.503	8.719
Calcic chlorid	———	3.675	23.624	28.047
Magnesic sulfate	20.124	———	———	———
Magnesic chlorid	———	9.802	3.655	2.952
Magnesic nitrate	———	———	20.699	20.522
Potassic sulfate	1.404	———	———	———
Potassic chlorid	———	2.369	———	———
Potassic nitrate	———	———	4.899	4.021
Sodic sulfate	14.854	———	———	———
Sodic chlorid	26.067	1.589	———	———
Sodic nitrate	36.078	40.258	33.820	35.077
Iron and Aluminic oxid	0.285	0.452	0.323	0.247
Silicic acid	0.102	0.317	0.397	0.415
	100.000	100.000	100.000	100.000

The location of this land is such that we cannot account for the presence of the large amount of nitrates by supposing them to have been brought into the area by surface waters and scarcely by underground flows. The seepage in this case is probably largely due to leakage from an irrigating ditch and in some measure to the excessive use of water by a neighbor, but the acreage from which such water might come is too small to account for the conditions as we find them. This land, like the most of our lands, contains the so-called alkalis.

Case No. 21—This is the same as No. 4 given in Bulletin 155, page 18. The reason for mentioning it is that it presents conditions which contrast quite strongly with the last instances given under the captions of Nos. 19 and 20. This piece of ground has been so dry every time that I have visited it, that it has seemed impossible that the nitrates should develop if I am correct that there is a minimum quantity of water necessary for its most rapid development, and that this minimum is rather high. Without having made any experiments to determine this amount I would judge it, according to my observations, to be above 18 percent of the weight of the soil. The bacteria can, without doubt, survive long and pretty thorough drying, and if a favorable degree of moisture be supplied at any time they are ready to develop. Whether they be able to endure greater changes in conditions than other kinds of bacteria or not is a question that I know nothing about, but unless I am greatly in error in the whole matter, the conditions in the present case become of considerable interest in this discussion. In discussing Nos. 19 and 20, as well as in my statement of the general proposition, I have connected it so closely with that of seepage that some may infer, as I know that some have already

done, that there is no nitre problem independent of seepage even though I have, perhaps, gone almost to a ludicrous extent in digging holes and giving the depth of the water table, the character of the soil and the drainage conditions to show that the death of the trees and other vegetation had not been brought about by an excess of water *per se,* and I have further given analytical data, as it seems to me in superabundance, to show that it is not due to an excessive amount of other salts which we think may be injurious.

I shall deal with this latter subject more fully in another bulletin, wherein I shall try to set forth more facts in detail which pertain to the effects of the presence of excessive water, large quantities of alkalis, and the presence of nitre—for the time being it will suffice for the fair-minded to consider that in the most disastrous cases—and I use this adjective advisedly, granting the reader the privilege of reading into it as much pessimism and prophecy as he may desire—that I have described; have been on land which has been set to orchards for from twelve to twenty-eight years, well drained and otherwise well cared for, in some cases it has been excessively irrigated to combat this very trouble, which shows that in some cases the natural conditions and the intelligent efforts of men have combined to prevent the accumulation of either water or salts leached from adjacent lands, which we have furthermore shown do not contain nitrates, and yet we have recorded the utter destruction of a twenty-seven or twenty-eight-year-old orchard in the short period of six weeks. If this were the only destruction wrought I would not at all be justified in using the language that I have used, or even in presenting the subject, except from its purely scientific side, but it is not a thing which has happened in one piece of land, nor in twenty pieces of land, but in very many pieces scattered over hundreds of square miles—not in patches of a few square feet but in large areas which, though irregular in contour are practically continuous for five, ten or even more miles. While the scientific features of the problem are of primary interest to me and the most of my readers, the magnitude of the land values involved and the questions of the future add reality and an importance to this question which the public has failed to recognize, or recognizing fear to acknowledge. There is a saying the "Fools rush in where angels fear to tread." Perhaps I have done this. Neither my folly nor courage alters the fact that the damage already wrought is immense, and I have elsewhere stated that unless something intervenes—what it may be we cannot forsee—the situation is serious. This is the practical side of the question.

The conditions obtaining in this case are the justification for presenting it as they emphasize the distinctness of this question from those of seepage and alkali. The land is on a hillside with a

south and southwest aspect. Six years or more ago water was stored in a reservoir in the northeast corner of the field. My information is that this reservoir was used for about four years but has not been used within the past six years. The field was in alfalfa four years ago. It was broken up and in 1908, set to apple trees. The area is, I think, 20 acres, possibly more. About four acres of the trees died. This land was reset in the spring of 1909. So good as none of the new trees lived. By midsummer of 1909 the area of dead trees had extended to twice its original size. In 1910 there are from twelve to fifteen acres on which but few trees are living.

Plate VI, lower Fig., a photograph taken Oct. 29, 1910, shows how large a portion of this field is wholly barren, not even Russian thistles or other weeds being able to grow on it. The rows that show in the plate are furrows between the rows of corn planted this season but which did not grow. That the land has been irrigated this season and the last time, at least, with a good flow of water is evidenced by the washing of the soil in the bottom of the furrows. Aside from this one piece of evidence most observers of this crop and the trees would raise the question whether the land had not suffered from neglect at the hands of the manager and for the want of water. I did not attempt to determine the depth of the watre table in this case as there is a deep wash at the west side of this hill not more than a few feet from the corner of this field, and there is, at this place, no water coming in above the bed of the wash. This land is underlaid by a shale at varying depths in different parts of the field. The trouble in this case began prior to 1907, as I was informed, somewhere about the middle of the land shown in the foreground of the plate. I took a sample of the surface soil in March, 1909, and another October 29, 1910, from almost the same place in the field. The former was taken to a depth of two inches, and the latter to a depth of four inches.

The analyses of the water-soluble portion of the two samples follow:

ANALYSES	LXXV	LXXVI
	Water-Soluble Laboratory No. 759	Water-Soluble Laboratory No. 1026
	Percent	Percent
Calcic sulfate	18.986	26.940
Magnesic sulfate	29.771	19.972
Potassic sulfate	1.387	1.109
Sodic sulfate	39.914	43.117
Sodic chlorid	1.474	1.661
Sodic nitrate	8.173	6.631
Ferric and Aluminic oxid	——	0.348
Silicic acid	0.295	0.222
	100.000	100.000

The water-soluble in No. 759 amounted to 8.23 percent of the air-dried mass; that in No. 1026 to 5.277 percent. These samples were taken nineteen months apart. The difference in the depths to which the samples were taken is unfortunate as the reader will be apt to overlook this in comparing them. I found No. 1026 entirely free from chlorin after the third washing, but the sample was rich in calcic sulfate and some difficulty was experienced in washing out the last of it as it was almost impossible to filter the well washed soil. The difference in the amount of water-soluble is less than one might expect, considering the different depths to which they were taken.

Cases Nos. 22 and 23—These are adjoining orchards and ordinarily would be considered as cases of seeped land. I shall say but little about orchard No. 23 for all that may be said of No. 22 is applicable to No. 23, except that No. 22 is a more recent development. The soil of these orchards is mostly a sandy loam but in places this is either underlaid or wholly displaced by gumbo, a calcareous, clayey soil which when thoroughly wet retains water wonderfully well. We attempted to dig a hole in one of these orchards but the ground was so tough that we abandoned digging and tried to force a bar down to water. We were assured before we began that we would not succeed, not only because of the character of the ground, but also because the water was not so near the surface as we imagined. We succeeded in putting the hole down nearly four feet but without striking water; the gumbo was, however, extremely sticky. An idea of the manner in which this soil holds water may be conveyed by the fact, related to me, that shortly after we dug this hole a heavy shower filled it with water which did not seem to pass into the soil at all and was removed apparently by evaporation. That this ground was not always in this condition is proven by the fact that the apple and other fruit trees had lived for thirteen years and made a good growth in this soil. Further, the dying of the trees in parts of this orchard in which these conditions do not obtain shows that the wet, sticky conditions did not kill the trees but are themselves caused by the conditions which bring about the death of the trees. I have elsewhere suggested this because of the peculiar condition met with in the soil, but in this case because it seems to follow directly after the other trouble. The statement has been made in connection with several orchards that while the soil itself was practically a mud there was no proper water table found at depths of six to six and one-half feet. In the present case we did not succeed in digging to a greater depth than a little less than four feet, but the house stands at the edge of the orchard and a little lower if anything than the point where we tried to dig. The

cellar under the house is stated to be about eight feet deep in which water rises and falls with the seasons. From this we found that at the lower edge of this very bad area the water plane was almost exactly six feet below the surface, at the end of the irrigating season. The cellar was dry when dug, now six years ago.

This orchard has taught us quite a number of things. We have been able to observe the death of the trees in a zone at the edge of this bad area just as the brown color extended. There was no trouble during the thirteen years of the life of the trees when no "black alkali" appeared, but as soon as this "black alkali" appeared the trees began to die; some of them began to burn and died within two weeks. From one-half to three-fourths of an acre died between August 18 and October 29, 1910, while other trees not more than twenty-five feet away remained in fine condition. In this case the trouble continued to spread till the end of the season. I did not learn whether there was any relation between the times of irrigation and the virulence of the attack on the trees and the rate of their dying. The manager has recently written to me that he irrigated this orchard about the first of December, 1910, and that the surface of the ground became intensely brown immediately after the application of the water even at the north end.

A hole dug just north of this orchard encountered a little water at four and a half feet, but the shale beneath this, to a depth of five feet more was entirely dry. A tile drain has been laid the entire length of the north side, varying from four to six feet in depth. My information is, that it is entirely dry.

The water is not in the irrigating ditch long enough, during the season, to affect the area in question. I asked the manager of this orchard repeatedly in regard to the possibility of the trouble being due to water and he as often repeated his answer that he could not believe it to be due to this cause. The depth of the water table, as shown by the water in the cellar, six feet, with very little variation throughout the year, supported his view. The water table, as indicated by the water in this cellar on December 28, 1910, was seven feet two inches, giving us a variation of fourteen inches for the year. The accompanying plates from photographs kindly furnished me by Professor Sackett, illustrate the condition of the land and orchard October 29, 1910. Fig. 1 indicates the upper and Fig. 2 the lower figure in the plate. Plate V shows the condition of a Paragon tree which had not been affected at the time the photograph was taken while Fig. 2, Plate III, shows a tree which died between August 18 and October 29. The tree at the extreme right of Fig. 2, Plate V is the next tree immediately east of Fig. 1, same Plate. Fig. 1, Plate V shows no brown areas while Fig 2 shows them very well. Fig. 2, Plate III shows a tree killed since August 18 and entirely denuded of leaves. The

photograph looks southward and shows that portion of the land from which the trees had been removed. There was white alkali showing on a portion of this area at the time the picture was taken but it cannot be distinguished from the sunshine on unstained ground. The white patches in the other figures are due to sunshine. Fig. 1, Plate V looks westward into that portion of the orchard not yet affected. Fig. 2 of the same plate looks eastward across the affected area. Fig. 2, Plate III looks southward across the worst portion of the land while Fig. 2, Plate IV looks northward toward the still healthy portion of the orchard as the background shows. It will be noticed that the third row and even some trees in the second row were in good condition at the time the picture was taken, October 29, 1910, but they died so rapidly that in the spring of 1911 five rows of these trees including the row of dead trees in the foreground were dug up and by June four more rows of trees had been killed.

The following are analyses of white alkali, water-soluble portions of this soil, and the ground water.

Laboratory No. 996, white alkali within bad area, 18.67 percent soluble in water.

Laboratory No. 1027, white alkali within area where trees were killed, 22.71 percent soluble in water.

Laboratory No. 1029, soil from orchard designated, Case 23, surface of soil brown, trees dying, 11.44 percent soluble in water.

Laboratory No. 999, water taken from cellar August 18, 1910, total solids 14,230 p. p. m.

Laboratory No. 1040, water taken from cellar December 28, 1910, total solids 17,561 p. p. m.

Laboratory No. 1028, surface soil, composite sample, one to two inches deep. No white alkali, trees dead, 3.11 percent soluble in water.

Laboratory No. 1046, brown, mealy soil four inches deep, composite sample, 1.29 percent soluble in water.

Laboratory No. 1041, water collected from sixteen-foot hole January 6, 1911, total solids 22,100 p. p. m.

ANALYSES	LXXVII	LXXVIII	LXXIX	LXXX
	Water-Soluble Laboratory No. 996 Aug. 18, 1910	Water-Soluble Laboratory No. 1027 Oct. 29, 1910	Water-Soluble Laboratory No. 1029 Oct. 29, 1910	Water-Residue Laboratory No. 999 Aug. 18, 1910
	Percent	Percent	Percent	Percent
Calcic sulfate	7.607	8.979	18.873	4.942
Calcic carbonate	———	———	———	4.536
Magnesic sulfate	31.447	24.794	36.407	19.604
Potassic sulfate	3.986	0.859	1.330	0.719
Sodic sulfate	52.776	56.877	28.816	59.415
Sodic chlorid	4.137	4.332	8.235	7.214
Sodic nitrate	———	4.017	6.094	3.688
Iron and Aluminic oxid	———	Trace	0.076	0.085
Silicic acid	0.047	0.142	0.169	0.117
	100.000	100.000	100.000	100.000

ANALYSES	LXXXI	LXXXII	LXXXIII	LXXXIV
	Water-Residue Laboratory No. 1040 Dec. 28, 1910	Water-Soluble Laboratory No. 1028 Oct. 29, 1910	Water-Soluble Laboratory No. 1046 Feb. 1, 1911	Water-Residue Laboratory No. 1041 Jan. 11. 1911
	Percent	Percent	Percent	Percent
Calcic sulfate	10.946	41.451	44.886	6.208
Magnesic sulfate	41.809	6.020	0.081	37.659
Magnesic chlorid	———	9.296	8.768	———
Potassic sulfate	1.012	———	———	1.210
Potassic chlorid	———	1.021	2.727	———
Sodic sulfate	33.267	———	———	51.876
Sodic carbonate	———	———	———	2.422
Sodic chlorid	7.726	19.234	15.847	0.556
Sodic nitrate	5.083	21.377	26.640	none
Iron and Aluminic oxid	0.080	1.203	———	———
Silicic acid	0.077	0.398	1.051	0.069
	100.000	100.000	100.000	100.000

This orchard presents three distinct problems—seepage, alkali, and nitre, which questions present themselves in the following forms, First, has the water collected in this area to such an extent as to make the land unfit for ordinary agricultural purposes unless it be drained? Second, is the concentration of the so-called alkalis so great that they alone have caused the difficulties? Third, have the nitrates brought about this soil condition and also caused the death of the trees?

I simply state the facts as we have found them and as they are exhibited by the analyses given. I long ago made the assertion that Colorado has no alkali question which does not resolve itself into one of drainage, and again, that I have not seen any crop seriously injured by alkali alone though I have seen some crops drowned out. Even soils that are very rich in the sulfates of soda, magnesia and lime will, if they be not at the same time all too wet, grow crops, sometimes good ones. In these cases it is the water rather than the alkali that does the damage. This is not the case with nitre, it kills trees and other plants in a characteristic

PLATE VI.—Upper Fig. represents wash mentioned in Case 13, p. 35. See also p. 60.

No. 1 is the upper figure

way when there is no excess of water, as we have demonstrated by experiments.

In regard to the water question in this case the facts are not clear. I have given the depth of the water plane as seven feet and stated that the annual variation above this is probably not more than ten or twelve inches. These statements are based upon the heighth of the water in the cellar of the house standing at the lower edge of the low portion of this land and also upon the results obtained by digging a hole nine feet deep and extending it by means of a post-hole auger to sixteen feet when the water rose to within seven feet of the surface. These figures were given to me by the manager of the property and are entirely reliable. The water at sixteen feet is evidently under some hydrostatic pressure but not enough to force it nearer to the surface than seven feet. The cellar referred to is a large one, 25x50 feet, and I think gives the true heighth of the water plane. These statements are not made to indicate that the surface of the land is not wet, for it is, but to indicate that the wet condition of the surface is not due to a high water plane but to surface waters. This water near the surface is probably none other than irrigation water, it is certainly not due to the run-off from heavy rainfalls, and is not due to leakage from an irrigating ditch to the north of the orchard. A salready stated holes or wells dug north of the orchard but south of the ditch did not show much water and a trench from fou rto six feet deep, dug the whole length of the orchard developed no water. The only water that could collect on this ground would be that used in irrigating about twenty acres of land. The orchard must no wbe fifteen years set and so the concentration of salts by washing and evaporation must have been going on this long at least. During this time, however, some may have been carried away by run-off waters.

Laboratory No. 996 is a sample of white, effloresced alkali and contained no nitrates. No. 1027 is a sample of surface soil and alkali taken two months later than No. 996 from another, but a very bad portion of the land, in my judgment, the worst. No. 1029 is a sample of alkali and soil taken from an adjoining orchard indicated as Case No. 23 which is wholly neglected by its owner and no further mention will be made of it. No. 1028 is the water-soluble portion of a soil sample taken October 28, 1910, one and one-half inches deep. There was no white alkali at this place and the soil was in fine condition, but the trees were dying, the water-soluble in this sample was 3.11 percent but the nitrates present were equal to 0.676 percent of the sample. No. 1046 is another sample of soil taken Feb. 1, 1911, about four inches deep. This sample was taken west of the bad ground by taking smaller samples, uniting them and cutting down the mass to a convenient size. The water-soluble equalled 1.25 percent of the soil and the nitrates

amounted to 0.333 percent of the air-dried sample. No. 999 is the residue obtained by evaporating a sample of the water taken from the cellar, August 1910, to dryness. The residue equalled 996.1 grains per imperial gallon or 14,260 p. p. m., while No. 1040 is a similar sample taken December 28, 1910 carrying 1229.27 grains per imperial gallon or 17,561 p. p. m. These samples cannot be taken as actually representing the ground water owing to the fact that concentration due to evaporation must have taken place. The dimensions of this cellar as stated are 25x50 feet and while the house is built over it the cellar windows were open and we are uncertain in regard to the changes in it principally due to concentration. The first water observed in this cellar came in in the winter of 1908-1909 or about eighteen months before the sample 999 was taken and the analyses present the following results: the white alkali which had effloresced contained no nitrates; the white alkali mixed with some soil from slightly higher ground contained some nitrates, one twenty-fifth of the weight of the water-soluble; but the soils which would ordinarily be considered as free from alkali contain nitrates equal to one-quarter of the weight of the water-soluble.

The present owner of this land has put in upwards of 15,000 feet of tile drains. I saw about 7,000 feet of the trenches open in the very worst part of the land. The surface of the land was muddy as though they had recently had a heavy rain or the land had just been irrigated, the second spit was decidedly dryer than the first and while there was some water in the bottom of the trench, here and there filling the depressions made by uneven digging, by far the largest portion of it was entirely free from running water. I was very much surprised at the small amount of water appearing in so great an aggregate of trenches. It should, however, be stated that water flows out of such land with exceeding slowness. The fact was that the very surface of this bad land was the wettest portion of it and my impression is that this was always the rule with it. The land at the north end of the orchard is dry and, as previously stated, I was informed by two men, both interested in the success of the work, that the drain trench, from four to six feet deep, developed no water whatever. The effect of ground water upon the trees depends upon the depth at which the roots actually feed as well as upon the heighth of the water plane and the capillary power of the soil. I saw this trench when it was partially dug and I called the owner's attention to the fact that it was rarely the case that the roots were more than ten inches deep, though we occasionally found them, small fibrous roots, fourteen inches deep. The manager informs me that some of the trees in this section of the orchard burned in the autumn of 1910 which seems to be very probable as they are practically dead in the

spring of 1911, in fact a number of trees have been dug up in this portion of the orchard, just how many I do not know, but all of the trees shown in our photographs taken in October, 1910, seventy-five of them, have been removed, but by June 3, 1911 many more trees, nine rows in all, back from the foremost row in Fig. 2, Plate IV have died since August 18, 1910. All of this land is in good physical condition, mellow, well cultivated and free from water.

The white alkali collected in August, 1910 shows no nitrates, that collected from a very bad spot, in October, shows a rather small percentage, 4.017, and as this was surface alkali and soil it does not necessarily indicate a large aggregate amount. The samples of soil taken where there was no white alkali, while giving a low percentage of water-soluble, showed the presence of very large amounts of nitrates, 21.377 and 26.640 percent. While the trees did not die last year, 1910, where these samples were taken, they did die in May of 1911 as soon as the trees put out their leaves.

All of these trees and all others referred to through this and previous bulletins as having been killed by nitre, die in the same manner, with the symptoms produced by the direct application of sodic nitrate.

The water samples in this case are particularly interesting. The samples taken from the cellar, one in August, the other in December, 1910, are both quite rich in nitrates. The richer one of the two carrying approximately one and a third tons per acre-foot of water. The important question is whence these nitrates? The water had begun to come into this cellar about twenty three months prior to the taking of the last sample and the significance of the results depends upon the answer given to this question. The natural, and in this case, correct answer is unquestionably from the surface. The sample of water, No. 1041, taken from a hole sixteen feet deep in all, is very much richer in total solids but contains no nitrates. I take it that this represents the ground water proper of the section and agrees with the ground water proper of other sections showing that the nitrates are not transported to the affected areas by this means.

The destruction of this orchard has proceeded very rapidly. It began in the early summer of 1910 and at this time, June, 1911, almost the whole of a fifteen-acre orchard has been destroyed.

Case No. 24.—This is a very interesting occurrence. The land was sown to sorghum in the summer of 1910, but the crop was a complete failure. There is a large irrigating ditch running possibly six hundred feet to the north of it. The land is somewhat low but there is an orchard close by, in fact is immediately south and east

of it and without knowing the actual difference in level I would estimate it as not greater than two feet. The field immediately north of this property was in beets, which were very poor indeed. This fact is mentioned to indicate that the people still considered it as tillable ground. The question of seepage is of course suggested by its position, but I dug shallow holes three to three and a half feet deep on different occasions without striking water. I was surprised that the water plane was so deep as three feet, but it was evidently deeper. I expect to give in a subsequent bulletin the best possible proof that beets will grow well and yield beets of fine quality with the water plane much nearer the surface than this, and I have seen a fine growth of sorghum on land in which the drainage ditches were not as deep as this. While I willingly admit that in my judgment the people did unwisely to choose these pieces of land for cultivation, they probably did not believe that the land was seeped at the time of planting or was likely to become so during the season, and as I have already indicated, I found no reason for thinking that the water plane was at any time less than three feet below the surface. I dug one of the holes referred to in June, the other in September, 1910. The general conditions that prevail are as I have just described them, but these alone would scarcely have induced me to have made mention of this land, though it is one worthy of study in this connection.

Circumstances enable me to give a few facts pertaining to the effects of flooding. I stated in connection with Case No. 8 that the owner had irrigated excessively till, in his own language, he had "washed the ground white" in expectation that by so doing he would correct the evil. We had, however, no results except the continued bad condition of the land to indicate the effects. Further, I showed that the drainage of his land was ideal. Again in connection with Orchard No. 3, described in Bulletin 155, I stated that the owner of that orchard had treated some of his land in the most drastic manner in an endeavor to correct this difficulty by washing. This party had run a furrow with a turning plow, followed with a subsoil plow and turned into the furrow one hundred inches of water but without any satisfactory degree of success; this statement is very conservative. The last time that I saw this man's orchard it and some of his other land was in a very bad condition. This flooding had leveled the land but it had not removed, if it had indeed alleviated the trouble for any considerable time.

I can, fortunately, present the effects of flooding in removing the salts and benefiting the soil in this case. I chanced to be in this section of the state on the 12th of August, 1910, when, due to torrential rains, the piece of affected land was flooded for about five hours. The flood waters which swept acress it were several inches deep. I learned that about a week subsequent to this another

flood, due to the same cause, covered this land to a depth of two feet and that it was twenty-four hours before these flood waters had entirely disappeared. The flow of these waters, as indicated by the straw, weeds and other debris lodged on the posts and fence wires, was evidently strong, and the depth assigned, i. e., two feet, was probably correct; furthermore it had left very little or no sediment. I had taken a sample of the mealy surface soil on June 6, 1910, so I was glad for the opportunity to obtain a sample of the surface soil from as nearly the same place as I could locate it from memory, on September 25, 1910, not more than thirty-five days after the last flood. On this date I dug a second hole to see how near to the surface the water plane might be, and as stated before it was not within three feet either in June before the floods or in September after them, so the drainage of this land must be reasonably efficient. I may add that the soil at this place was sandy to the depth that I dug, while that of the beet field north of it was heavier, inclining to clay.

ANALYSES	LXXXV Water-Soluble Laboratory No. 956 June 6, 1910 Percent	LXXXVI Water-Soluble Laboratory No. 1038 Sept. 25, 1910 Percent
Calcic sulfate	7.535	14.126
Magnesic sulfate	12.130	16.097
Potassic sulfate	3.154	2.777
Sodic sulfate	59.793	58.432
Sodic chlorid	13.361	6.934
Sodic nitrate	3.817	1.296
Silicic acid	0.210	0.338
	100.000	100.000

The water-soluble in No. 956, taken in June was equal to 15.35 percent of the air-dried sample, that in 1038, taken in Septemper equalled 9.533 percent and the nitrates, as sodic nitrate, equalled 0.582 and 0.123 percent of the respective samples. It is really an accident that we are able to give these data relative to the effects of these floodings and while they are far from complete they may serve to give us some idea of what we may expect to accomplish by trying to wash the soil, i. e., it will be a much more difficult problem in practice than it is in theory. It would have been very interesting to have been able to determine the distribution of the nitrates in this land immediately after the second flood and to have determined the rate a which they made their reappearance at the surface, for a rapid evaporation must have taken place from the surface of this land at this season of the year. One, however, would think that the flowing of such a volume of water over this land, as occurred on these two occasions, would have extracted and removed the nitrates rather than to have carried them

down into the soil, for it is to be remembered that this land was covered several inches deep by a mass of water moving at a rather rapid rate for five or more hours about August 12, and again about August 20, to a depth of two feet for twenty-four hours. How much nitrogen as nitrates this flood water may have contained I do not know but it could not have been any relatively large quantity. The waters of a reservoir used in irrigating this section of country contained only a trace when last analyzed, now several years ago, and the return waters as represented by a sample of river water analyzed at the same time contained 1.5 p. p. m. Further, this water flowed off of and did not evaporate on this land, so I do not think that the question of transported nitrates is to be considered. The sample taken in September indicates, so far as it is worthy of consideration, that these floods removed approximately four-fifths of the nitrates present as indicated by the sample taken in June.

Case No. 25—This case is given because it presents an example of drained land. The area is twelve acres; it is much longer than wide, the west and south sides being represented by an irregular curve, the field being bounded by a low hill, along the flank of which runs an irrigating ditch, but its supply of water is not good so it is often dry. The owner thought that the bad condition of the land was due to an excess of water. It is now something over five years ago that he put in three lines of tile drain, from four to six feet deep. I have no map of this drainage system but two of the lines, I was informed, run lengthwise of the field for its whole length, and the third one is a line run with the idea that it would intercept the water that leaks from the irrigating ditch and deliver it into the main drains. I do not know the depth of the water table, but I do not think that it is at any place materially above the depth of the drains, i. e., four feet. This land has now been planted to beets for five years in succession and the owner has never harvested a full crop off of all of the field, and for the past three years he has had so good as no crop at all. In October, 1909, I made a note to the effect that from one-fourth to one-third of the field was absolutely devoid of vegetation, even of weeds. I visited this field several times during the season of 1910, and if there was any difference the conditions were worse than in 1909, but they were very bad in both years and the crops were practically failures. Two roads intersect at the northeast corner of this field. The field east of this one and across the road was also planted to beets, the stand was in places poor, the ground brown and mealy; the beets were, as a whole, poor. The field northeast of it was not cultivated, its surface was brown and mealy, but the common sunflower was growing in spots and was very luxuriant. I took two samples of soil about three inches deep, one near the south end and the other

from the north end, on October 11, 1909. The surface at this time showed nothing unusual as a rainfall of 0.83 of an inch had fallen three days before, on the eighth of the month. The surface at this time was not muddy or wet. The sample from the southern part of the field, Laboratory No. 867, contained 2. 564 percent; the one from the north end contained 3.315 percent of material soluble in water.

ANALYSES	LXXXVII	LXXXVIII
	Water-Soluble Laboratory No. 866 Oct. 11, 1909	Water-Soluble Laboratory No. 867 Oct. 11, 1909
	Percent	Percent
Calcic sulfate	28.672	32.729
Magnesic sulfate	14.156	11.468
Potassic sulfate	4.345	3.495
Sodic sulfate	28.779	18.150
Sodic chlorid	17.197	28.256
Sodic nitrate	6.435	5.410
Iron and Aluminic oxid	0.162	0.070
Silicic acid	0.254	0.422
	100.000	100.000

We have in each of these samples essentially 0.16 percent of the top three inches of the soil consisting of sodic nitrate or its equivalent in other nitrates. Even beets have not grown in this soil for four years.

Case No. 26—This is as typical a location for seepage as I think can be found anywhere, not excepting Cases Nos. 22 and 23. The difficulty here has been unhesitatingly designated by the double term seepage and alkali by all local parties concerned up to the present time. The configuration of the country at this place is that of a flat tract bordered on either side by rising ground, the flat section varying in width up to two hundred paces or more, through the central portion of which runs a drainage ditch three to four feet deep and about five feet wide. The portion of this higher strip of land in consideration is about twenty feet above the surface of the lower portion and from twenty-three to twenty-five feet above the bottom of the drainage ditch. Persons really familiar with drainage problems in Colorado will not be misled by the apparently simple condition stated above. In this case borings showed that the water table, in the lowest portion of the cultivated area, was, in November, five feet below the surface, and that the water table at a distance of six hundred and fifty feet south of the drainage ditch was only one foot above, while the surface of the ground at this point was six feet above the bottom of the ditch. As elsewhere stated we will subsequently show that the beet will thrive, producing a fair crop of excellent beets with the water table much

nearer to the surface than this. Borings to a depth of six feet and more at points more remote, failed to reach the water plane. Though the water plane at the lower limit of cultivated ground was five feet below the surface the soil was wet at a depth of two to four inches. The highest portion of this tract is the southeastern corner. The slope is from this portion, north and west to the drainage ditch. The central portion of this strip of land was planted to beets in 1908, 1909 and 1910, but we do not at this time intend to say anything about the beets nor about the land planted to beets, but will consider only the cultivated land west of this. I regret that I have no photograph of this land, for it is exceedingly difficult for any reader who has not actually seen these things to understand even the most faithful description or to have any adequate appreciation of the facts. In 1910 this land was planted to sorghum. There was here and there a little of it that came up but for the most part it was a complete failure, the land being entirely bare except along the irrigating furrows or lateral where, at the margin, showing the limit of the running water, a few small, stunted plants survived. These plants were not more than a few, from three to eighteen, inches high. I took a sample of this soil on November 2, 1910, weighing about forty pounds, and to depths varying from four to six inches. This sample was taken for experiments in incubation, but a preliminary test showed that the soil extract gave very unsatisfactory results, in fact, it was a failure. The azotobacter seemed to have been killed. The water-soluble portion of this soil equalled 4.518 percent of the air-dried soil. A nitric acid determination made on this sample corresponded to sodic nitrate equal to 38.867 percent of this water-soluble or 1.756 percent of the air-dried soil, being at the rate of 70,240 pounds of sodic nitrate per acre-foot; or restricting the calculation to the top six inches actually taken, we have 35,120 pounds, or 17.56 tons per acre, a degree of concentration which is very difficult for those who know nothing about this matter to believe possible.

The water-soluble in the following sample, 1024, equalled 5.54 percent.

ANALYSIS	LXXXIX Water-Soluble Laboratory No. 1024 Nov. 2, 1910 Percent
Calcic sulfate	18.377
Calcic chlorid	18.740
Magnesic chlorid	12.030
Potassic chlorid	1.882
Sodic chlorid	4.550
Sodic nitrate	32.997
Iron and Aluminic oxid	0.115
Silicic acid	0.219
	100.000

It is no wonder to me that the soil was mealy and barren and that our culture experiment showed no living azotobacter. The desirability of a series of nitric acid determinations as well as that of the total nitrogen in samples of such a soil taken at stated intervals is evident, but it has not been and scarcely will ever be feasible to prosecute this work in such detail in the field; there are other difficulties besides the remoteness of the locality from the laboratory. Had I forseen the developments that took place in this land in 1910 I could have arranged matters better. This is all that I wish to say about this case at the present time. I may say something more at a future time.

Case No. 27— This is a sample of earth taken from the roadside near a neighboring town. A vertical face of earth two and a half to three feet high left in working the road, as well as the flank of the road were decidedly brown and looked moist and oily. An irrigating ditch runs about sixty feet north of this point, the bottom of which is between four and six feet above it. There was no undue amount of moisture either at this point or on the other side of the road to indicate leakage from the ditch. The earth is a red, gypsiferous and somewhat sandy clay. The sample was taken from the surface, but a portion of it may have been more than an inch deep. The N_2O_5 present equalled 1.079 percent of the air-dried sample.

Cases Nos. 28 and 29—In this investigation only two occurrences of nitrates have been met with which must be considered as owing their origin to leaching from the soil. How far the nitrates in these two cases may have been transported is, as a fact, wholly unknown.

In the case which I have myself seen they probably came from the immediately surrounding country, as the line of hills about the place is not far away and the occurrence is clearly a surface one. These two occurrences are shallow wells, one of them twenty-seven

feet deep, the other said to be forty feet deep. I have not seen the latter, the water of which was sent to me. We had a little over two litres of water to evaporate down. It was a mistake that we adopted this method of procedure but it was too late to change it when this occurred to me. The water was not a fresh sample when we analyzed it. The total solid equalled 560.8 grains per imperial gallon, 8,012 p. p. m. This water is yellow in color, has a bitter taste, foams strongly when poured or aigtated and had no odor though the sample was old when its container was opened.

The following analysis has been calculated to one hundred:

ANALYSIS

	XC Water-residue Laboratory No. 1202 Percent
Calcic sulfate	35.926
Calcic chlorid	4.348
Calcic carbonate	5.105
Magnesic carbonate	4.095
Magnesic nitrate	44.939
Potassic nitrate	1.870
Sodic nitrate	3.717
	100.000

This analysis shows that the salts in solution are principally calcic and magnesic salts in which magnesic nitrate is particularly abundant. I know of this well only by correspondence . It was the only well in the neighborhood yielding such water, other wells near by yield sweet water.

The other well water to which I refer is also yellow. Its taste is at first cooling, afterwards bitter. It, too, foams on agitation or pouring. The well is twenty-seven feet deep, the water was encountered at the depth of twenty-three feet. The ground yielding it was described as one foot thick; no water came in below this. There was at the time I visited this place four feet of water in the well, i. e., the well was filled up to the top of the water-bearing zone. The well was not curbed except in the upper portion, but was provided with a ladder so that it was easy to go down into it. This well was sunk through a somewhat mottled clay. I took the mottling to be due to aggregations of calcic carbonate. This clay was tenacious enough to stand without peeling off or sloughing. There was no water entering above the twenty-three-foot point and no indications that any water had ever trickled down the sides. The owner has prospected his ranch for water by boring holes from eighteen to twenty-eight feet deep, without success. He has even dug a fifty-foot well which proved to be a dry one. This well is sunken for the most part in Niobrara shales. A little water, apparently a little pocket, was met with at a depth of forty

feet. This was said to have been good water but there was no quantity of it. The well, with this exception, was dry when dug and is still dry. The striking of water in the first well seems to have been an accident. The flow is not strong and comes from the direction of the higher land. The owner stated that one man could not pump the well dry but that two men taking turns could pump it out. The water is unfit for any use, even for irrigation. There were a few hills of corn near the well which had been watered with this well water; the corn was burned and I doubt whether it will survive. There were also some onions which did not show any effects of it. This well is near the owner's house and on ground sloping to the south. The land which the owner prospected for water by borings is lower and at times is flooded by rain water. The surrounding country is not irrigated and the rain fall is not sufficient for the growing of crops. The owner, who is holding the land in the hope that sometime it will be brought under irrigation, stated that he had not gotten enough out of his crops to pay for the labor expended on them. The source of the nitrates contained in this water is unquestionably, I think, the higher lying surface soil to the north of this place. Why the water should be confined, as it apparently is, to this particular area is not evident. There is nothing in the contour of the country to suggest a reason. The first sample of this water that I had, one which was sent to the Station by the owner, contained 1819.5 grains per imperial gallon or 25,993.0 p. p. m., the sample which I collected myself and shipped in glass gave 1692.6 grains per imperial galon or 24,180.0 p. p. m.

ANALYSIS	XCI Water-residue Laboratory No. 1077 Percent
Calcic sulfate	9.553
Magnesic sulfate	56.650
Potassic sulfate	0.769
Sodic sulfate	6.142
Sodic chlorid	3.266
Sodic nitrate	22.480
Iron and Aluminic oxid	1.140
	100.000

The question of the existence of brown spots here would seem to be excluded. Brown spots of course are taken as a positive indication of the presence of nitrates and of azotobacter. Such a concentration of nitrates in surface waters like these calls for a most extraordinary supply of nitrates or a very long period of concentration and the separation of the accompanying "alkali" salts. The activity of the bacteria is conditioned by temperature, moisture

and a neutral or an alkaline medium. The temperature and alkalinity prevail in this section and the only factor which is lacking is the moisture to bring about the formation of nitrates. The correctness of this view is indicated by the occurrence of the brown, greasy-looking spots along the irrigating ditch in a neighboring section of the country, where the land is similar though it is still native prairie. The conditions are not well enough known to justify definite assertions pro or con in these cases. I have not permitted myself to make any prophesises but simply to record the facts as I see them. It would, however, be very interesting to be able to watch the developments in this section for five years if it could now be supplied with an abundance of water for irrigation and we could grow a series of crops on these lands. This experiment, while altogether too big a one to be undertaken by an individual, will in all probability be made and while I cannot hope to be able to study it in detail, I do hope to be fortunate enough to be able to follow it in a general way. It will certainly be instructive to those who shall see it.

DISCUSSION

I have given a large number of cases but each case, with very few exceptions, represents different conditions—not only different from one another, but different from the conditions given in Bulletin 155. I have endeavored to give different conditions and at the same time widely separated localities and samples representative of large areas. The aggregate area described in Bulletin 155, was between eighty and one hundred acres. The area described in this bulletin aggregates more than three hundred acres, and does not include any of that described in Bulletin 155. This is only a very small part of the total area involved in the state. So far as its distribution throughout the state is concerned the areas given represent nine counties, extending from the Kansas boundary to that of Utah and from the Cache la Poudre to the Arkansas river, and even further south, to the New Mexican boundary.

The total percentage of the irrigated or cultivated lands affected by this trouble, to the extent of the instances given, is more considerable than we might wish, but it is not a large percentage of the whole, still if we consider it in square miles and bear in mind the value of the lands affected, as estimated by the owners, it becomes a very serious matter. The four hundred acres described in this and in Bulletin 155 are representative of large districts, I think that as a very conservative estimate we may state the districts affected as aggregating from three hundred to four hundred square miles. In a large portion of this territory the conditions are very bad. The most serious feature is that these very bad portions may only represent extreme developments of a general condition which

exists in our soils which only awaits the occurrence of some optimum condition for its excessive development. One of the factors in this optimum condition is an ample and continuous supply of moisture.

The question of the influnece of the character of the soil has been frequently raised since the publication of Bulletin 155. The wet condition of two of the soils described in that bulletin tended to leave the impression that the whole trouble might be due to water, especially in the minds of readers who might consider the wet, muddy condition of the soil the only cause for the death of the trees, and not to consider this condition itself as the result of conditions other than the presence of water. It was distinctly and repeatedly stated in Bulletin 155 that the water in these cases was not free so as to form a water table at depths of six to six and a half feet. In the case of Orchard No. 3, I stated that the land where the sample of mealy, surface soil was taken was sandy and that the ground was only fairly moist at a depth of six feet. In Cases 5, 7, 8 and 9 we again have sandy and in part light clayey loam with sandy subsoils, and no excess of water at depths reached by the roots of the trees. In the Cases of Nos. 8 and 9 we have excellent drainage. In these cases, especially in the latter, the trouble can in no manner be attributed to an excess of water. Still Case No. 9 was one of the most severe ones that I have yet seen, though it is underlaid by a stratum of gravel at a depth of from five and one-half to eight feet. The same is true, in different measures, of Cases 10, 11 and 12. The soil in Case No. 10 is decidedly sandy with a stratum of coarse granitic gravel at a depth of only three feet and yet this land is in such bad condition that the owner has not yet, after repeated attempts, succeeded in getting his fruit trees, peaches and pears, to grow. In Case 12 a beautiful orchard has been destroyed outright in one season. This point is not a matter of opinion but one of fact, and for this reason so many cases, to which Cases Nos. 16 and 20 might be added, have been given. The conclusion is evident that the trouble is not due to the presence of an excess of water, nor to the character of the soil for these sandy soils have shown it to as great a degree as heavier clayey soils of which Cases Nos. 6 and 12 may be cited as examples. No. 6 is an especially bad case, but the results were no worse than in Case 9—they could not be, for two and one-half acres of large trees were killed within a few weeks. The attack in Case No. 6 was not so violent nor did it involve so much ground at one time.

The trouble is not to be attributed to ordinary alkali. In Case No. 8 a part of the orchard is free from the nitre but is rich in ordinary alkali; the trees have died only in the nitre area. There are many orchards scattered throughout the fruit growing

sections which have been planted on ground rich in alkali, which are in good condition. Nearly every case cited in which an orchard is involved is one in illustration of this fact. Cases 5, 6, 7, 9, 11, 12 and 21 were old orchards, from fourteen to twenty-eight years old, in which the trees had thriven till within a few weeks before their death. The soils in these orchards are not richer in alkalis now than they have been in years past, nor richer than the soils of many other orchards which are still in a flourishing condition. Water does not kill so quickly nor in this manner.

The trouble in the cases of orchards is not at all related to the age of the trees, for trees of all ages have been killed. Older trees with large root systems seem to be more readily affected than younger trees but I have seen a nine and an eighteen-year-old tree standing within twenty-five feet of one another attacked and killed in practically the same time.

This trouble has spread very rapidly since the summer of 1909 when I first observed bad attacks in orchards. Orchards Nos. 1, 2, 3 and 4, mentioned in Bulletin 155, had been observed previous to that time, but during the past year, 1910, I have seen many orchards, distributed over a wide area, seriously injured. In former years I have seen no injury done in May or early June, but this year, 1911, the damage already wrought is large and the outlook is very ominous.

Orchard lands are by no means the only lands in which this trouble occurs, other lands are as badly affected as are the orchard lands, but orchard lands are conspicuous because of dead or dying trees, or of vacancies caused by the removal of dead trees. Cases 19, 20, 24, 25 and 26 are examples of ordinary cultivated lands.

Apple trees have been mentioned so nearly to the exclusion of others that one might think that the apple is the only tree or plant that is killed. This is not the case. The following trees and other plants have been noted: the apple, pear, peach, plum, apricot, cherry, quince, maple, cottonwood, ash, currant, grape, corn, tomato, bean, pumpkin, cantaloupe, pea, elm, willow, Lombardy poplar, Carolina poplar, sorghum, oats and barley.

I have made no experiments in addition to those recorded on pp. 43 and 44 of Bulletin 155, to demonstrate the effect of nitre on apple trees. The results of those experiments were stated as follows: "The effects were in all respects similar to those produced in the affected orchards, the beginning and progress of the effects, the killing of the leaves, the throwing out a few whitish-yellow leaves, their speedy death and the appearance of the bark and wood after death, were identical. An application of large quantities of salt proved injurious but did not produce these effects." The experiments, eight of them, were concordant and conclusive.

The only new thing that I have noticed during the past year in the deportment of these dying trees was their tendency to come into bloom in September and later. Sometimes a tree would put out quite a sprinkling of bloom.

The question of concentration of nitrates has also been suggested. I had this question in mind when, in Bulletin 155, I referred to the popular idea that the irrigating waters bring the "black alkali" to the surface, and discussed the fact that some seepage waters issuing from certain shale banks contain significant quantities of nitrates. It was then shown that the shales contained no more nitrates than could be readily accounted for by assuming their origin to be in the soils of the mesas above them, which assumption is suggested by the occurrence of areas which are very rich in nitrates on various parts of these mesas. Case 19 in which we find a very considerable number of such occurrences stretched along for a distance of probably five miles, is one in point. This area lies above and extends southward from the point where the shale sample showing 0.03 percent of nitrates was taken. The intensity of the fixition or fixation and nitrification which has taken place in this area is indicated by the analyses given in connection with this case. While many of these occurrences made their first appearance in 1909 and 1910, over 2.0 percent of nitrates was found in an alkali collected on this mesa in 1907 and the aqueous extract of a soil sample taken the same year, 1907, contained nitric acid equivalent to 6.00 percent of sodic nitrate calculated on water-soluble or nearly 0.40 percent calculated on the air-dried sample. It is evident that leaching from the shales cannot possibly account for the occurrence of nitrates in the soils many feet above them. A similar argument applies to all of the geological formations occurring within the affected territory, i. e., they are wholly inadequate to account for the observed occurrences which are found above as well as below the various strata which might be taken as illustrations; in other words, the occurrences are wholly independent of the geological formations.

It may be further mentioned that no other occurrences of nitrates have been found either in excavations, borings or elsewhere which might be considered the source of any of the nitrates. Again, as previously urged, the general distribution of these nitrate patches requires for its explanation the existence of some very widely distributed source or generally occurring cause.

The fact that these nitrate spots are generally associated with wet land has led to the idea that the ground and even ditch waters may be accountable for them and consequently that drainage will obviate the trouble. It would in some cases be of decided benefit to drain the lands, and might possibly change the location of the nitre area by changing the area in which the condition of optimum

moisture prevails, but my observations lead me to have little hope for immediate and satisfactory results from drainage. In Case No. 8 I gave the conditions of the ground and those of adjacent lands in some detail for the purpose of showing that these adjacent lands do not furnish the nitrates and that the ground water would not, even if it flowed into this land, Case No. 8, account for the presence of any nitrates as they are not present in this ground water, nor yet are they, the nitrates, contained in the white, ordinary alkali of the surrounding lands which is essentially a mixture of sulfate and chlorid of sodium.

In regard to drainage, Cases Nos. 8 and 9, light clayey to sandy loam soils, with sandier subsoil underlaid by gravel, located on the river bank and from 12 to 15 feet higher than the river bed present ideal drainage conditions, and yet these cases presented, in 1909 and 1910, extreme instances of very high degrees of concentration of nitrates with most disastrous results, so far as the orchards and crops were concerned.

The ground water from the adjacent land but also the drain water from an adjoining similar soil showed actually less nitrates than is often present in good drinking waters, yet there is a very rich nitre patch near the river bank east of this drain. We have in this connection conclusively shown that such drain water cannot be the source of the nitrate. It is easy to suggest various explanations and remedial measures as applied to individual cases, especially if they are simply suggested explanations without regard to a wider range of facts, or suggested remedies never to be taken seriously as the basis of acts. The facts in such cases as have just been cited do not support these suggestions nor commend these remedies. Drainage, for instance, so far is I know, has given in these cases mostly disappointing results. Cases Nos. 8, 13, 15, 24 and 25 can all be interpreted in this sense. Apropos to this point I may mention the statement of a field agriculturist in answer to my question relative to the general results obtained by drainage; his answer was that they were generally more or less disappointing. We have cited two instances, Nos. 8 and 9, in which nature has made a perfect application of this remedy and it proved wholly inadequate to ward off or to mitigate the evil. I know of no more intense instance of this trouble than is presented in Case No. 9, while Case No. 8 is very bad. In the latter case the successive owners have combated the trouble persistently for about seven years. They have tried the application of extremely large quantities of manure, frequent and thorough cultivation, also frequent and excessive irrigation in the endeavor to wash out what they thought to be black alkali. Prior to 1904 there was no trouble with this portion of the field; it was as good and as productive as the rest of the land, but from that time on it has been

bad and has slowly grown worse during the time that I have had it under observation.

It may be wise to state that it is not intended that any one should infer that I doubt the value of drainage in removing excessive water from land, but simply to state that at the present time I do not believe that we have much reason to hope for any material relief from this trouble by drainage, even in cases of comparatively low lands, while it is wholly out of the question in cases of high or naturally well drained lands. If these lands could be kept covered with water to a depth of several inches, twelve or more, for a number of days and then be thoroughly drained out the aerobic bacteria might in this way be killed off and the excess of nitrates removed; but this could be applied to small and favorably located areas only; the costs would be heavy and the permanency of any benefit doubtful. This, however, has not yet been tried.

Cases Nos. 8 and 24 of this bulletin and No. 3 of Bulletin 155 present the facts relative to what we may hope from flooding or persistent washing of the soil more fully than any others that have come under my observation. Case No. 8 is particularly instructive because the drainage is apparently perfect and it received twelve profuse irrigations in the season of 1909, and yet in 1910 the puffed and mealy condition of the soil was as bad as I had ever seen it and the surface soil was very rich in nitrates. The effort made in 1909 to wash out this soil was apparently futile, and we have shown by analyses of the soil, of alkali and of the ground water from adjacent lands that these nitrates do not come from these sources and the nitrates found in 1910 do not represent a resupply from this source. There is no question but that these nitrates can be temporarily washed out of the soil, but they were as abundant, if not more so, in 1910 than they were in 1909 when the land was irrigated twelve times in the endeavor to wash out the "black alkali." I have presented in Case No. 24 an analysis of a sample taken in June which, as I take it, represents the salts present in the surface soil under ordinary conditions; also of a second sample taken in September, because this ground was flooded twice in the month of August, once to a depth of two feet which required 24 hours to flow or drain off. The easy solubility of the nitrates makes it a matter of surprise that we should find about a month subsequent to the last flooding not only so large an amount of soluble salts but also so large a quantity of nitrates present. Case No. 3 was given in Bulletin 155; in this case the owner had tried for 16 years to bring these spots under subjection; he had plowed and flooded, but without success. I have not as yet seen or learned of any result obtained by flooding which gives any solid basis for expecting very permanent, beneficial re-

sults from this operation. Perhaps frequent and repeated flooding combined with drainage, where needed, might prove effective.

If the nitrates are not present in the various geological strata and there are no local deposits scattered all over large sections of the state in which we may find the source of these nitrates occurring in our soils, the question, Whence do they come? is germane.

The facts stated in connection with Case No. 8 are, I believe, perfectly applicable to all other cases and it can be stated, without any material modification, that these nitrates are not the product of concentration of ground waters flowing from other lands as they, these ground waters, contain no nitrates; neither did the soil, examined to a depth of three feet, nor the white or common alkali which was abundant on this adjacent land contain any nitrates in 1907. Further, they are not due to the concentration of surface washings.

There is one remote possibility, which so far as I know, has not been suggested, i. e., the water used for irrigation. While this is an extremely remote possibility, we can answer the suggested question. We have sanitary analyses of several of the river waters, also of reservoir waters, which are used for the purposes of irrigation, and the nitrogen present as nitrates varies from a trace to 0.400 part per million, a quantity not only too insignificant to be considered a factor in the problem, but so nearly zero that it shows that there are no nitrates in the rocks of the drainage areas of these rivers to which the nitrates may be traced.

The answer that I suggested in Bulletin 155 was that these nitrates are formed where we find them. That the nitrogen is taken from the atmosphere by azotobacter and is subsequently changed into nitric acid, respectively nitrates, either by the azotobacter themselves or by other bacteria. So far in this bulletin I have presented facts in abundance to establish the occurrence of very large quantities of nitrates in certain of our soils, and that the concentration in hundreds—I am fully justified in saying thousands—of instances, is most remarkable, but all proof adduced bearing upon their origin has been by a process of exclusion, i. e., the nitrates are present but they have come from nowhere, therefore they are formed in *situ*.

In Bulletin 155 I showed by nearly 300 nitrate determinations that many of our soils contained very notable quantities of this substance. At the time these determinations were made, October, 1909, we found this quantity varying from 12 to 1,920 pounds per acre in the top six inches of soil, calculated as sodic nitrate. These samples were from cultivated fields in good condition which had been planted to beets. The highest results were obtained in the turn rows.

I have been unable to find any more satisfactory data relative to the amount of nitric nitrogen in soils than was given in Bulletin 155, page 37, based upon Rothamsted results which showed that in lands cultivated as bare fallow about 80 pounds of nitrogen were converted into nitrates in 14 or 15 months. This includes the nitric nitrogen removed in the drain waters. If this amount were all present at one time and contained in the surface foot of soil it would amount to only 0.002 of one percent. In the top 18 inches of another field they found in September and October 49 pounds of nitric nitrogen. If this were all contained in the surface foot at a given time it would correspond to 0.001225 percent. The statement is made that this large amount is due to the richness of the soil in nitrifiable matter, showing that 49 pounds per acre to a depth of 18 inches was considered high, if not unusual. The ratio of the nitric nitrogen to the total nitrogen at any time is not given. It is well known that the nitric nitrogen present in soils varies from time to time owing to several causes, but the easy solubility of the nitrates makes it very probable that the amount of them in the surface soil will be dependent upon the amount of rainfall and the time which has elapsed between the last rainfall and the taking of the sample. The character of the soil, i. e., the readiness with which it allows water to pass through it, its power to retain the nitrates, and the evaporation which takes place from its surface will also influence the amount of nitric nitrogen present at a given time. Rainfall does not usually play the important part with us that it does in England or in the eastern states; if it ever does, it is only for short periods of time.

The samples of soils used for the determination of nitric nitrogen in Bulletin 155, pp. 38 and 39, were taken at the close of a wet season, that is, for Colorado. We had had 3.36 inches of rainfall between September 12 and December 1, and .47 inches during the month of December, and yet we found a maximum of 320 pounds of nitric nitrogen in a set of 46 samples taken between October 1 and 15. The samples were taken to a depth of six inches. In another set of 54 samples taken January 26-31, we found a maximum of 280 pounds of nitric nitrogen in the top six inches of soil. It is to be remembered that these samples were from fields which had been planted to beets. The last sample was taken from the turn row. These quantities are so materially higher than those given for Rothamsted soils, though these Rothamsted fields had been cultivated as bare fallow, that we can scarcely compare them at all. In the case of the 80 pounds of nitric nitrogen per acre in the Rothamsted soils the nitric nitrogen removed by drainage has been determined and included. In these Colorado samples only the nitric nitrogen which was present in the soil to the depth of six

inches at the time the samples were taken is considered—drainage or greater depths are not considered.

I have the record of a considerable number of analyses of our Colorado soils and they scarcely average over one-tenth of one percent total nitrogen which, judged by ordinary standards, cannot be said to be more than a fair supply of nitrogen.

The prairie soils of Illinois, as given in their Bulletin 123, contain from two to four times as much, and even their subsoils contain more nitrogen than our surface soils. The soils of Kentucky, Bull. 126, are likewise much richer in total nitrogen than ours. Storer, Vol. II p. 76, says that Krocker, and Payen also states that cultivated land seldom contains less than 0.10 percent of nitrogen and that they usually contain a much larger quantity. He states further that A. Mueller found, on an average, 0.26 percent of nitrogen in the surface soils poor in lime and 0.15 percent in their subsoils. In the surface soils of limestone regions he found, on an average, 0.66 of nitrogen.

King states that the mean amount in eleven arable soils at Rothamsted is placed by Lawes and Gilbert at 0.149 and for eight others at 0.166 percent. Four Illinois prairie soils were shown by Voelcker to contain 0.308 percent; seven Russian soils according to C. Schmidt contained 0.341 percent. The average of these thirty is 0.219 percent. Lawes and Gilbert gave four Manitoba soils as containing 0.373 percent of nitrogen. Hilgard states that from 0.1 to 0.2 percent of total nitrogen in non-acid soils is considered adequate.

Our Colorado soils are non-acid soils. I have as yet, found but one case of an acid soil, not considering beds of peat. In seventy-three analyses of Colorado soils taken in various parts of the state twenty-two of them contain less than 0.1 percent total nitrogen and fourteen contain 0.2 percent or more, leaving thirty-seven or a little over a half of the samples considered which contained 0.1 percent and more, but less than 0.2 percent. It is only a few weeks since, that an analysis of a Colorado soil was submitted to me for my interpretation. The reason for this was that parties in Illinois having the purchase of a tract of Colorado land under consideration had a sample of the soil analyzed and as it contained only 0.08 percent of nitrogen or a trifle less, they, I understood, declined to buy it.

Other soils from sections of this state have, according to reports, been found to be deficient in nitrogen and yet these soils produce excellent crops of corn and wheat. According to our analytical data there can be no question but that many of our soils, according to the standards adopted, are low in nitrogen but they produce excellent crops, in favorable seasons, 60 and even 80 bushels of wheat to the acre, while from 35 to 50 bushels per acre

are common yields. The standards adopted and our analytical data are not in perfect harmony with the common facts of actual practice. This has been observed by others and is not new. Trained and practical agricultural chemists who have had years of experience in this state, have stated to me that they had not observed any indication that our crops ever suffer from the lack of nitrogen, and they were perfectly well aware of the fact that according to analytical results many of our lands are deficient, or at best only moderately well supplied with this element.

In regard to the ratio of nitric nitrogen to the total nitrogen in soils the statement that it, the nitric nitrogen, seldom amounts to 5 percent of the total is attributed to Warington. This may be taken as a maximum. There is recorded in Bulletin 126 of the Kentucky Experiment Station, 24 analyses of soils in which both the total and the nitric nitrogen have been determined, which show that the nitric nitrogen varies from 0.0 to 1.263 percent of the total nitrogen present. The total nitrogen in the sample showing the largest amount of nitric nitrogen was 0.238 percent of the soil. The land from which this soil sample was taken had been set to tobacco which had failed. The authors, A. M. Peter and S. D. Averitt make the statement: "The effect of the large amount of nitrate was evident in the better growth of the wheat where the tobacco failed." In another case in which the nitric nitrogen amounted to 0.826 percent of the total nitrogen the authors make a similar statement. "The larger proportion of nitrate where the tobacco was poor is to be noted here, as before, and the effect of this upon the wheat was very apparent." The authors consider these quantities of nitric nitrogen as large and apparently as injurious enough to account for the bad condition of the tobacco. In our Laboratory No. 697 we find the total nitrogen equal to 0.080 percent of the soil, which is probably a little too low, while the nitric nitrogen in the same sample equalled 0.0377 percent of the soil or 47.07 percent of the total nitrogen. This was a sample taken to a depth of twelve inches. It is a very bad soil but not nearly so rich as some samples with which we have met, especially in the cases of surface samples. In Case No. 6 the surface foot of soil, which proved to be an exceptional one, as it was poorer in nitric nitrogen than the second foot, the nitric nitrogen constituted 1.86 percent, in the second foot 1.9 percent and in the third foot 55.3 percent. This is almost the only instance in which we find more nitric nitrogen in the deeper samples than in the shallower ones. The surface soil is not included in the sample designated as the first foot. The nitric nitrogen in the surface portions of this soil, taken perhaps thirty feet north of where these soil samples were taken, amounts to 0.053 percent of the air-dried soil or 530 parts per million. The total nitrogen in this surface sample was

not determined. Judging from results in other samples, the nitrogen was probably almost wholly present as nitric nitrogen. In a series of 54 soil samples taken to a depth of six inches the minimum of nitric nitrogen equalled 1.5 percent while the maximum, debarring an execptionally high one, was 17.1 percent of the total nitrogen. I have already cited an instance in which the nitric nitrogen in the third foot of soil was equal to 55.3 percent of the total nitrogen, this, however, was an exceptional sample, not in the amount of nitric nitrogen present but in the location of the nitric acid in the soil.

The nitric nitrogen in other, mostly surface samples, ranges from 16 to 93 percent of the total nitrogen. The latter percentage, 93, seems extremely high but the total nitrogen was determined in duplicate and the determination of the nitric nitrogen was also made in duplicate by different parties, using slightly different methods of preparing the material for the determination of the nitric acid. The agreegent between these determinations was entirel ysatisfactory. The difference falling in the third decimal place. Two samples, our No. 1054 and 1055, illustrate the great variation in the amount of nitric nitrogen in affected and unaffected soils. No. 1054 is a sample of surface soil taken to a depth of four inches near to a recently killed tree, while No. 1055 is also a sample of surface soil taken from supposedly unaffected ground 600 to 800 feet north of the former and just outside of the orchard. No. 1054 contained 0.0932 percent total nitrogen and 0.0150 percent nitric nitrogen, or 16.09 percent of the total; No. 1055 contained 0.0844 percent total and 0.0003 percent nitric nitrogen or 0.355 percent of the total. The soil conditions were entirely different in these two cases though they were relatively close together.

Fixation—In Bulletin 155 I presented the fact, ascertained by Professor Sackett, that the aqueous infusion of some of our soils induced a very marked fixation of nitrogen, the maximum given at that time being 13.02930 milligrams in 20 days for each 100 c. c. of mannite solution. The questions pertaining to the relation of the azotobacter to fixation and nitrification may be worked out in detail by Professor Sackett, but I have endeavored to determine the practical facts on a large enough scale to be conclusive so far as these processes in our soil are concerned. For this purpose I took five portions of soil of 1,250 grams each. The moisture content was determined at 100° and boiled, distilled water added to make the total water equal to eighteen percent of the moist soil. The weight of the dish and soil was determined and noted in order to be able from time to time to add water enough to replace loss due to evaporation. At the same time

samples of the soil were brought to a thoroughly air-dried condition and the total, and also the nitric nitrogen determined. Four of the large dishes with their charges of soil were placed in an incubator and were kept at a temperature of about 29° C. for 27 days, when a sample was removed from each dish for examination. The fifth dish was covered and placed in an unused room.

Two of the four dishes placed in the incubator were inoculated by the addition of 25 grams of another soil in which the total and nitric nitrogen was determined, because a culture test made from the sample of soil taken for this experiment gave unsatisfactory results, as no proper membrane was formed, only a few gelatinous masses at the edge of the culture medium. I feared that I would have to collect other samples of soil and repeat the experiment, as I had already had to do once, for the first sample of soil that I gathered for this purpose, though it was very rich in nitrates, seemed to contain no living bacteria which Professor Sackett, on whose judgment I relied, was willing to accept unqualifiedly as virile azotobacter. This precaution, however, proved to be unnecessary, for a sample of soil taken from the fifth dish, on the thirteenth day of the experiment, gave a very heavy membrane in four days. The soil in this dish had already begun to show a change of color on its surface at the time this sample was taken. The membrane in the culture flask began to show brown points by the eight or ninth day. This fifth dish had been kept in a south room where for part of the day it received the sunshine, modified by a screen of paraffined paper. We have five dishes, each containing originally 1,250 grams of soil with eighteen percent of moisture. On the twenty-seventh day I removed from each dish 170 grams of the moist earth, brought it to a thoroughly air-dried condition and made nitrogen determinations in triplicate on each sample. I have mentioned five samples, but I added another, i. e., a sample of the original soil which had been put into a show bottle while moist and allowed to stand in the room. If moisture, air and an equitable temperature be the requirements for the fixation of nitrogen I could see no reason why I should not expect an increase in this sample as well as in those placed in the incubator, perhaps not so great an increase, but still an increase. Samples A, B. C and D were put into the incubator, sample E was moistened and kept at the room temperature and F was the original sample in its moist condition.

The original soil, thoroughly air-dried, gave 0.105875, 0.11000 and 0.105875 percent of nitrogen, average for total nitrogen 0.10725 and 0. 0035 percent of nitrogen as nitrates, equal to 3.263 percent of the total.

	Percent total nitrogen at the end of 27 days.		Milligrams gained per 100 grams soil in 27 days.
Sample A gave	0.11688 0.11688 0.11963	Average 0.11779	10.54
Sample B gave	0.11550 0.11688 0.11825	Average 0.11688	9.63
Sample C gave	0.11413 0.11413 0.11413	Average 0.11413	6.88
Sample D gave	0.11550 0.11413 0.11550	Average 0.11504	7.79
Sample E gave	0.11275 0.11275 0.11413	Average 0.11321	5.99
Sample F gave	0.11275 0.11130 Lost	Average 0.11207	4.82

The fixation obtained and given in Bulletin 155, p. 46, is given for each 100 c. c. of the culture medium. In order to make the figures easily comparable we have given these results in milligrams per 100 grams of soil. The soil experimented with was simply a good, arable soil collected from the College farm at or near a point where I had observed the development of brown patches. It is not one of the soils in which we have observed excessive quantities of nitrates but even here the nitric nitrogen amounts to 3.27 percent of the total. The quantities fixed in 20 and 30 days in a mannite solution inoculated with an infusion of 10 grams of soil are exhibited in the following table along with the fixation accomplished in these samples of soil in 27 days. The inoculation of the two samples seems to have made no difference whatsoever.

NITROGEN FIXED

	Milligrams in 100 cc. in 20 days	Mannite-Solution in 30 days	Sample	In 100 grams of soil in 27 days
Sample 1.	0.00000	1.05075	A	10.54000
Sample 2.	1.19085	0.56040	B	9.63000
Sample 3.	3.08220	3.43245	C	6.88000
Sample 4.	6.16440	12.46890	D	7.79000
Sample 5.	0.84060	3.08220	E	5.99000
Sample 6.	0.77055	3.57265	F	4.82000
Sample 7.	3.50250	3.01215		
Sample 8.	2.38170	2.87205		
Sample 9.	13.02930	10.15725		

All of the ordinary analytical precautions were taken and the nitrogen obtained in the blank test, also run in triplicate, has been deducted. Each of the seventeen separate determinations made on these six samples show a decided increase in the amount

of nitrogen. In this climate I find that the thoroughly air-dried material presents almost as good a basis for comparison as is possible for us to get, which would not be the case in a humid atmosphere.

When we consider the nitrification we find equally interesting results. As already stated, this sample of soil contained at the beginning of the experiment 0.0035 percent of nitrogen as nitrates, on the twenty-seventh day of the experiment the various samples gave the following:

NITRIC NITROGEN IN SOIL SAMPLES INCUBATED FOR TWENTY-SEVEN DAYS.

	Percent in Soil		Percent of Gain
Sample A.	3/3	0.0055	54.29
Sample B.	3/3	0.0057	62.85
Sample C.	3/3	0.0060	71.43
Sample D.	3/3	0.0065	85.71
Sample E.	3/3	0.0036	——
Sample F.	3/3	0.0043	22.85

These results show clearly that both fixation and nitrification took place in all of the samples except E, in which nitrification is insignificant or zero, while the fixation amounted to 5.99 milligrams per 100 grams of soil. At one time one of the dishes in the incubator smelled distinctly of butyric acid, but this odor disappeared within a few days and all of the dishes had the pleasant odor of fresh soil when the samples were taken out of the dishes.

The remaining portions of the samples, after having been thoroughly wetted with boiled, distilled water were returned to their original positions and only a little more water, not weighed, added till the forty-eighth day when this series of experiments was terminated. Four of the dishes were replaced in the incubator. One dish was covered and placed at the bottom, the other three dishes were not covered as in the first period except as each succeeding one served as a cover for the one next below it. The top one of course was without any cover. Two beakers, containing water, were also placed in the incubator to aid in saturating the atmosphere with moisture and to lessen the evaporation from the soil. The moisture in the samples on the forty-eighth day was determined and found to be for A, 13.5, for B, 14.5, for C, 17.0, and for D, 20.0 percent. These are the four dishes placed in the incubator. Sample E, which was kept in a covered dish at the temperature of the room, contained 17.5 percent of water. The moisture in sample F, which was the original soil kept in a show-bottle, was not determined.

		Percent of total nitrogen in soil at the end of 48 days.		Milligrams nitrogen gained by 100 grams soil in 48 days
	1	0.12276		
A	2	0.12144	Average 0.11968	12.43
	3	0.11484		
	1	0.11484		
B	2	0.11748	Average 0.11748	10.18
	3	0.12012		
	1	0.11616		
C	2	0.11880	Average 0.11792	10.60
	3	0.11880		
	1	0.11484		
D	2	0.11748	Average 0.11660	9.30
	3	0.11748		
	1	0.11616		
E	2	0.11880	Average 0.11924	12.00
	3	0.12276		
	1	0.11484		
F	2	0.11356	Average 0.11529	7.99
	3	0.11748		

Sample E, which contained 17.5 percent of water at the end of the experiment and had received direct sunlight every day, developed quite a growth of algae, showing on the surface as green and brown spots. These proved to be, for the most part,oscillaria and diatoms, which became very evident in a culture of these made on sand. The incubator samples of course showed no growth of this sort, but sample A made even a larger gain in total nitrogen and the same gain in nitric nitrogen as sample E on which the algae grew. So it is not clear whether the algae exercised any influence upon the result or not. The gain in both total and nitric nitrogen was, however, much more marked in sample E during the second period of the experiment than in any other sample during this period. The order of the samples in regard to gain during the second period is E, C, F, A, D, B, but in no case had reverse changes set in to such an extent as to wholly conceal the increase. It is, perhaps, unfortunate that I did not extend the examination of the soil to include the ammoniacal and nitrous nitrogen at the beginning and end of the experiment as well as the total and nitric nitrogen.

Returning to the increase of total nitrogen in the soil it may be well to state it in terms of perecntage, calculated on the amount of nitrogen originally present. Such a statement gives us for A, 11.589; E, 11.188; C, 9.883; B, 9.492; D, 8.671 and for F, 7.449 percent. The maximum gain calculated on the amount of nitrogen present at the beginning of the experiment is 11,589; the minimum 7.49 and the average for the six samples is 9.712 percent.

The gain of the total nitrogen in the case of sample F, is worthy of special note. This sample was the original just as it

was gathered and put into a round bottomed bottle loosely closed with pieces of paste board and allowed to stand in the room where the sun shone on it part of the day. In this case we find a gain of 7.99 milligrams for each 100 grams of soil in 48 days, equal to 7.449 percent of the nitrogen originally present. In this connection an observation made in 1900 is interesting. The observation is noted in Bulletin 65, p. 45, and raises this question of the increase of nitrogen in samples kept in the laboratory for some time, in the case mentioned, fifteen months, though air-dried, bottled and corked but not sealed. We found a gain of twenty-eight pounds of nitrogen per acre-foot, too small to be conclusive.

Nitrification—The original sample contained nitric nitrogen at the beginning of the experiment equal to 0.0035 percent, and at the end of forty-eight days, the samples contained the following amounts:

		Percent nitric nitrogen in soil at end of 48 days.		Gain in percentage of nitric nitrogen originally present in 48 days.
A	1	0.0060		
	2	0.0060	Average 0.00600	71.43
	3	0.0060		
B	1	0.0060		
	2	0.0060	Average 0.00587	67.71
	3	0.0056		
C	1	0.0080		
	2	0.0070	Average 0.00750	114.24
	3	Lost		
D	1	0.0080		
	2	0.0090	Average 0.00833	138.00
	3	0.0080		
E	1	0.0060		
	2	0.0060	Average 0.00600	71.43
	3	0.0060		
F	1	0.0040		
	2	0.0040	Average 0.00417	19.15
	3	0.0045		

These tables show beyond a question that both fixation and nitrification have taken place, the former in far greater degree in absolute, but the latter in an even more marked degree in relative measures. In two samples the nitric nitrogen has much more than doubled.

All of these samples except F had become decidedly darker on the surface than they were at the beginning.

We have in these samples the reproduction of the main features presented in our fields, the production of nitrates, the fixation of nitrogen and the browning of the surface soil. The water content of the samples was chosen at about 18.0 percent because my observations in the field have led me to the conclusion that the

optimum amount is probably below rather than materially above this percentage. The determination of the optimum amount of moisture under specific and varied conditions would be interesting but is a detail not included in the general features which I am endeavoring to present. We have the maximum nitrification in the sample containing 20 percent of water at the end of the experiment. My judgment is that this amount had scarcely varied at all during the experiment. On the other hand we have the maximum fixation in the two samples containing 13.5 and 17.5 percent respectively. These results may be accidental but they agree well with my observations in the field. The amount of fixation, however, is quite uniform and the addition of water, at least up to 17.5 percent has clearly promoted it.

The chemical composition of this soil is fairly represented by our Laboratory Nos. 724 and 725, representing the soil and subsoil from a portion of this same tract. These analyses were given in Bulletin 155, p. 36.

ANALYSES	XCII Soil Laboratory No. 724 Percent	XCIII Subsoil Laboratory No. 725 Percent
Insoluble	54.653	57.068
Silicic acid	19.805	12.754
Sulfuric acid	0.047	0.049
Chlorin	0.032	0.059
Phosphoric acid	0.120	0.127
Carbonic acid	3.048	6.312
Lime	6.100	8.465
Magnesia	1.355	1.448
Sodic oxid	0.290	0.432
Potassic oxid	0.872	0.742
Ferric oxid	5.601	3.499
Aluminic oxid	3.738	5.397
Manganic oxid	0.118	0.026
Ignition	5.072	3.887
Sum	100.851	100.265
Oxygen equiv. to chlorin	0.007	0.013
Total	100.844	100.252
Total nitrogen	0.147	0.069
Humus	0.426	

While these analyses are not made on the soil actually used they serve to represent its composition as well as a sample taken in any fair-sized field may represent its soil.

The amount of nitrogen fixed is very large and seems incredible. Taking 10.54 milligrams as the quantity fixed in 100 grams of soil in twenty-seven days and calculating the amount that would be fixed in the top two inches of the soil per acre, we have 937 pounds, or for an acre-foot 5,622 pounds, equivalent to about 17.5 tons of proteids (N x 6.25) per acre-foot, a quantity which seems extremely large, but this is the result actually obtained.

The maximum gain in nitric nitrogen calculated per acre-foot per annum corresponds to five tons of sodic nitrate.

Perhaps emphasis should be laid on the fact that these soil samples experimented with were, as stated, samples of an ordinary soil collected from the College farm at or near a point where I had observed the brown color which serves me as a guide and which I suggested was probably due to the brown azotobacter pigments. Further, that nothing was added to the sample except distilled water which had been boiled to expel any trace of ammonia that it might contain.

However puzzling the facts may be they are simple; the nitrates are present in large quantities in areas scattered over 300 to 400 square miles as a conservative esitmate. These occurrences of nitrates are independent of geological horizons and do not owe their origin to the neighboring or surrounding country. Nitrates occur in some lands surrounded by others in which nitrates do not occur. They are not present in the alkalis or the ground waters occurring in these surrounding lands; again, they occur on elevated mesas at such heights and under such conditions of location, that they could not be accounted for in this way, i. e., as concentrations from other lands. · On the other hand we have shown that both fixation and nitrification take place in our soils, in a notable degree, and we have every reason to believe, because of the observed intense local developments, that our results, obtained with the samples of soil from Fort Collins, are much less intense than those actually produced in many localities. I know that there are questions unanswered, but it seems to me that it makes little difference to the facts, whether we know whence comes the energy which is assumed to be the *sine qua non* for the development of azotobacter or not, the fact is, they do develop. In our case a culture test at the beginning of our experiment gave unsatisfactory, but not absolutely negative results; another sample taken from one of the dishes, not inoculated, after a period of 13 days gave in four days a very strong membrane. The two samples were in no way comparable in their development. There were positive indications on the surface of the soil in the dish that it was becoming brown before we took the second sample. The rapid and profuse growth of azotobacter in the culture medium indicated either a very greatly increased abundance of the bacteria themselves or an immensely increased virility. The question of whether the azotobacter both fix the atmospheric nitrogen and convert it into nitric acid, respectively nitrates, or whether this latter work is done wholly by another genus or other genera of bacteria is, perhaps, a question to be settled—but, be it settled as it may, our facts remain the same that we have instances of the accumulation of very large quantities of nitrates in our soils always associated with the brown color which

we know to be caused by the azotobacter. I believe, and this belief is based upon tentative facts, that the azotobacter are at the same time nitrifiers, i. e., that the possess a double function which I believe has already been asserted but not generally accepted. I will state that Professor Sackett is not in any way responsible for this view and I do not know his attitude on this specific subject. These matters of theory and function are open ones but the fact of fixation of nitrogen and the formation of nitrates in our soils to such an extent as to kill fruit trees and ruin the land are established ones.

I expect to present another bulletin in the immediate future dealing with another phase of the subject, i. e., the general effects of the nitrates upon the sugar beet, which will also continue these soil questions.

SUMMARY

The problems presented involve the occurrence of nitrates in such unusual quantities, that I may say, I hope without offence, that even the oldest and most experienced men have not seen the equal of it and have no conception of the facts.

These nitrates occur so abundantly on very many square miles of otherwise good land as to be either prejudicial or fatal to vegetation.

The apple tree has practically been adopted in this and preceding bulletins as the criterion whereby to judge of the intensity and extent of the injurious effects of the nitrates, though other trees and crops, especially the sugar beet, have been mentioned.

The damage done to apple orchards in this state is very serious. If we should estimate the trees killed within the past two years as equivalent to six hundred acres of orchard I believe that it would be a conservative estimate.

These injurious effects of nitrates in cultivated soils are so new and so extensive that we cannot wonder that the layman or even the scientific man who has not seen them, fails to grasp them as facts or if they do and realize their importance, that they hesitate to acknowledge it.

The trees all die in the same manner. This applies to the apple, pear, peach, apricot, willow, elm, cottonwood and other poplars, and to vegetation in general.

Experiments were made with sodic nitrate by applying it to apple trees, when it produced the same effects on the leaves and killed the trees in the same manner as these orchard and shade trees are observed to die.

This series of experiments, eight of them, was not repeated because the results were concordant and conclusive. Experiments were also made using sodic chlorid, common salt, in sufficient quantities to injure the foliage. The effects were unlike and easily distinguished from those produced by sodic nitrate.

The manner of attack, the effect produced and the very rapid termination of the trouble in the death of the trees indicate the action of the same cause.

The identity of these effects with those produced by sodic nitrate, and the presence of very unusual quantities of nitrates in all of the soils where this trouble is met with are accepted as conclusive proof that the nitrates are the cause of it.

No attempt has been made to determine the limit of tolerance of the apple tree or other plants for nitrates. It has, however, been observed that an established beet plant can endure immense quantities of them, but not without deterioration in quality.

The problems presented are not those of ordinary alkali, nor of seepage, nor yet of the occurrence of nitrates produced in the soil by

nitrification as generally understood, but their occurrence in unusual, detrimental and fatal quantities, over areas measured by the square mile of territory.

The nitre question presents a distinct problem whose relation to the problems of alkali, seepage and drainage is not so intimate as is indicated by the statements made in Bulletin 155.

The statements of Bulletins 155 and 160 in regard to the cause of the "brown spots," the character of the salts present, their fatal effects upon vegetation and their extremely deleterious action upon the soil are corroborated.

The spread of the trouble during the year 1910 was very marked.

The intensity of the attacks has increased rather than abated.

Some instances of a very rapid development combined with extremely intense action have been observed. In one fourteen-year-old orchard not less than twelve acres of trees, apple, plum, pear and cherry, together with currant bushes and other small fruit have been killed in less than a year. The water table in this land was not, at any time, near enough to the surface to do any damage.

No single instance of the death or eradication of a brown area, a nitre spot, has been observed; but the interior of such areas has been found so excessively rich in salts that the ground has become barren, even of the azotobacter flora.

This deportment of the bacteria suggests the probability that the land may again become fertile after a few years, in fact, varieties of Atriplex, saltbushes, are already taking possession of land which has been devoid of vegetation for several years.

The drainage in several of the cases given is excellent, in other cases drains have been laid for periods of from one to five years without preventing the formation of nitre areas.

Trees badly affected by this trouble show almost no recuperative power, probably due to the continued excessive supply of nitrates in the soil, possibly to the severe toxic action of the nitrates. So afr as our observation goes both factors seem to be involved. Slightly affected trees may recover but no badly affected tree has been observed to do so.

The generally observed change in the soil, indicating danger to the trees, is a turning brown of the surface which is expressed by the statement that "The soil turned brown or black and the trees died."

The samples of brown soil have, without exception, contained excessive quantities of nitrates.

The color is not due to the nitrates nor to sodic carbonate or black alkali proper but to the development of pigments by the azotobacter. This applies to the soils here described. Some soils may have a brown color due to other causes.

This condition is usually preceded and accompanied by a mealiness of the soil, often described as ashy. There is usually but little or no efflorescence on such soils, though it sometimes occurs.

The time required for the killing of a tree varies with the virulence of the attack, in bad cases from four days to two weeks. Slightly affected trees may linger a long time.

These areas may occur in perfectly drained land, situated in the midst of land which shows no abnormal quantities of nitrates.

In one case, and possibly in others also, injury to many trees followed the application of water, probably due to the washing of the nitrates down into the soil.

The river waters used for irrigation, whether stored or not, contain no unusual quantities of nitrates.

The ordinary white alkali that commonly occurs in these sections is, for the most part, free from nitrates, but the brown and white areas frequently overlap.

The ground waters, unless derived from nitre areas, are free from nitrates and these nitrates cannot be accounted for by the evaporation of such water from the surface of these areas.

311
+ .90

In some sections practically the whole of the irrigated land has been affected, thus eliminating the question of transportation except as to the river water used for irrigation. Our river waters carry from 0.00 to 0.4 part per million of nitrogen as nitrates.

The localization of these areas and the rate of increase also preclude the theory of transportation and concentration.

Excessive irrigation for the purpose of washing out the "black alkali," nitrates, has not been successful, but this failure has probably been due to the method used.

The liberal application of manure has not given permanent, if indeed, any relief.

Thorough and frequent cultivation has not been followed by the beneficial results expected.

The soils of Colorado are, generally speaking, poor in nitrogen, but the ratio of nitric nitrogen to the total nitrogen is frequently very high, 17 to 50 percent being not uncommon.

The nitrogen in these soils is fixed by azotobacter which use the nitrogen in the air to build up their tissues.

The fixation of nitrogen, in a sample of ordinary soil from the College farm, collected December 12, 1910, on incubation for twenty-seven days, was found to have taken place at the rate of 5,222 pounds of nitrogen, equal to 17.5 tons of proteids per acre-foot of soil per annum.

The nitric nitrogen present in this soil at the beginning of the experiment corresponded to 840 pounds of sodic nitrate per acre-foot of soil; this had increased in 48 days to 1,999 pounds as a maximum, a gain of 1,159 pounds which would give, if this rate were continued for a year of three hundred and sixty days, a gain of 8,676 pounds, or four and a third tons of nitrates per acre-foot of soil.

The incubated samples, with but one exception, showed a darkening of their surfaces.

No addition of anything except boiled, distilled water was made to these samples before or during incubation. A large bottle was partially filled with some, approximately eight pounds, of the original sample just as it was collected. This bottle was loosely stoppered, inverted and kept in a room where the temperature was fairly high and even. This soil was analyzed just as the incubated samples were and showed a decided increase in both the total and nitric nitrogen, 7.45 and 19.15 percent respectively.

Fixation takes place rapidly in this soil in the presence of from 13.5 to 20 percent of water. The rate of fixation of nitrogen obtained is sufficient to account for the nitrates found in the soil provided that it is nitrified.

The rate of nitrification obtained is sufficient to account for the formation of the nitrates found, in most cases if not all of them.

The brown color of these soils is due to pigments produced by the azotobacter.

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BACTERIOLOGICAL STUDIES OF THE FIXATION OF NITROGEN IN CERTAIN COLORADO SOILS

BY

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BACTERIOLOGICAL STUDIES OF THE FIXATION OF NITROGEN IN CERTAIN COLORADO SOILS.

By Walter G. Sackett.

Somewhat over a year ago, Dr. Headden called my attention to the extremely large quantities of nitrates present in certain Colorado soils, stating at the time that these nitrates were frequently associated with a brown discoloration of the soil, and that this color was often confined to well defined areas varying in size from three feet in diameter to an acre or more; furthermore, that these so called "brown spots" were not fixed, inert quantities related to some recognized geological formation, but that they were alive, and in the process of making as evidenced not only by the rapid progress with which the then existing spots were spreading, but also by the almost continual appearance of new spots both in old and new localities.

Dr. Headden has been studying our alkali soils and drainage waters for the past sixteen years, and he tells me that complaints of "brown spots on which nothing will grow" have been common, but more so during the past five years; reports have been received from the cantaloupe growers that their melons are deteriorating in quality without any assignable cause; truck gardens, alfalfa, oat, barley and sugar beet fields have been developing barren patches where a uniform stand was always obtained in former years; in some parts of the state, the sugar content of the sugar beets as well as the purity and tonnage have fallen off until it is a ponderous question with the farmers and sugar factories whether the growing of sugar beets in those localities is any longer a profitable industry; but equally serious, if not even more so than any of these, is the destruction which is being wrought in some of the apple orchards of Colorado. Newly set trees, trees that have just come into bearing, and trees that are fifteen to twenty-five years old, in fact, trees of all ages, seem to suffer alike. It is not an isolated tree here and there that has died, but thousands, representing many acres of orchards in widely separated districts, have perished during the past two seasons.

When one is brought face to face with facts of such tremendous economic importance as these, he can scarcely fail to be impressed with the deplorable condition of affairs, and is forced to the position that something out of the ordinary is taking place, and that it is not without a cause.

With reference to the occurrence and distribution of the nitre areas, Dr. Headden gives the following in Bulletin 155 of this station:

"This trouble was not confined to any one section, but was common to several sections of the state. While it, in all probability, depends upon soil conditions, these conditions are met with in so many places that it is necessary to consider the condition rather than the soil

itself. It sometimes occurred in light and sandy loams, and sometimes in clayey soils. It is sometimes in comparatively low lying lands, again in the low lying portions of higher lands, and again on the hillsides. The road side, a ditch bank, and the cultivated fields represent the range of places in which this thing may reveal itself. There is one thing common in all of its occurrences, namely, a brown color in the surface soil. This color is less marked in the sandy soils than in the so-called adobe soils. Perhaps this is due to the presence of the deliquescent salts on the surface of the adobe soils, or more probably to the color of azotobacter films."

Fig. 1. Nitre area in an orchard showing the characteristic dark spots. Sample No. 30.

"We find the nitrates present in soils, where there is a great deal of moisture, but in places where there is too much water, the nitre does not appear. In little valleys and saucer shaped depressions in which the lower portions are too wet, there is no visible alkali, then follows a zone where white alkali abounds and above this the nitre is formed. I do not mean to say that there may not be nitre mixed with the white alkali, but that the nitre in such cases appears on higher ground than that on which the white alkali usually appears. Furthermore, it is not intended that anyone shall infer that it is only in valleys and depressions that the nitre occurs."

In driving through those districts which are suffering with this trouble, the most striking feature to one not conversant with the symptoms is the brownish, black and, to all appearances, wet condition of the soil. This can be seen along both sides of the travelled road, and often extends to the irrigating ditch, or fence on either side, and into the adjoining fields. I think of nothing which describes the color better than the appearance of soil where crude oil has been spilled, as is done frequently in orchards where oil pots have been used in heating, or, if you please, where the roads have been sprinkled with oil. A typical case of this sort is illustrated in Fig. 1, page 4. Considerable disappointment is experienced, however, when this blackened surface soil is examined for it is often found to be a dry crust, rather than a wet one, one-fourth to one-half inch in thickness, underlaid with one or two inches of material of a very mealy character, beneath which the soil looks like any other soil. Sometimes the surface is so moist as to be slippery, due, probably, to the presence of quantities of deliquescent salts. As one walks over a field in this condition and breaks through the hard crust, the sensation experienced has been likened to walking on corn meal or ashes.

Concerning the condition of the soil met with under the mealy layer, I can not go into details since Dr. Headden has treated this phase of the question very fully and completely in his publications, suffice it to say that free water is seldom found nearer to the surface than five feet, and in most cases the soil is in what would be considered a nice moist condition; again in the heavier lands, we may expect and do find them rather sticky near the surface and of a gumbo character as the water plane is approached.

The brown color often appears on the banks of the irrigating ditches, eight to ten inches above the level of the water, and along the upper edge of the irrigation furrows. Extending lengthwise of these, it manifests itself a few days after irrigation as broad bands of pigment which might easily be mistaken for manure stains, so far as color is concerned, especially if the field or orchard had been fertilized recently. It is not uncommon to find large tracts of land where the nitrates have become so abundant as to be deleterious to the crops, yet no discoloration is apparent on the surface. It is difficult to say in such instances whether no color is being produced or whether it is developing so gradually and uniformly that it can not be detected readily.

The economic outlook of this problem is, indeed, a serious one. Bushels of wheat have been planted on heavy nitre soils, and if it germinated at all, only a very small percentage ever came through the ground. Oats and barley have suffered the same fate. Corn has germinated in some fields, and made a sickly, yellow growth of six inches to a foot and then died. Sugar beets, if they grew at all, have gone to tops, while the roots have taken on all sorts of abnormal, irregular shapes, typical "tub-beets," to say nothing of the inferior quality of the beet from the sugar standpoint. Dr. Headden has collected

a great deal of data on this point which will be presented by him in due time. The money loss to the farmers in seed alone has amounted to thousands of dollars. But the orchardist has been unquestionably the heaviest loser, for not only has he been deprived of the crop for the current season, but he has also lost the trees upon which he is dependent for future crops, at least we have yet to see a single tree which has shown any indication of recovery. Added to this and worse than all, perhaps, is the utter worthless and hopeless condition of his soil for agricultural purposes. The apple, cherry, apricot and plum, all appear to suffer about equally, while the pear and peach, thus far, have exhibited marked resistance, the peach having been observed to suffer least of all.

The symptoms of excessive nitre in the soil as manifested in apple trees are so characteristic that it may be well to describe them briefly in passing. The first indication is the firing or burning of the leaves along the margins, beginning at the apex, extending rapidly along the edge, inward toward the midrib and downward toward the base until the entire leaf has turned brown. There is no occasion for anyone who is familiar with the yellowing of foliage due to lack of proper drainage to confuse this with the nitre burning, for the appearance of the leaves in the two cases is entirely distinct. Whole trees have been known to undergo this transformation in less than three weeks time. In fact, Dr. Headden reports having killed a four-year-old tree in an experimental orchard in four days by applying twenty pounds of nitrate of soda around the roots and then irrigating at once to bring the nitre into solution. In reference to the behavior of this tree, he says, "The effects were in all respects similar to those produced in other orchards" under natural conditions. If the burning of the leaves occurs early in the season, the trees will often exert a feeble effort to put forth a second crop of leaves. These are usually small, whitish leaves and inclined to be rather pubescent. Such trees, laden with one-third to one-half grown apples, seldom mature any fruit, and in all probability will be dead by spring. If the attack comes late in August or September, the chances are that the fruit will mature, but it will be undersized and of poor quality; no new leaves will be expected to appear and the old ones will cling to the twigs late into the fall. The following spring, it is very likely that an attempt will be made at leafing out, but as stated above the leaves will be small, yellowish-white and few in number, and by the middle of the season the tree will be dead.

Before proceeding further, I wish to make it perfectly clear that what I have said is not to be interpreted as applying to all of our arable land or to more than a very small percentage. While the matter is eminently serious, it by no means justifies the position that our agricultural interests as a whole are in jeopardy. Just how we shall meet these difficulties, and correct the trouble, we are not prepared to say at present, but we are hopeful. As our knowledge of the subject grows, we feel confident that remedial measures will be forthcoming

in the near future. In this connection, I may say that it is my purpose this coming season to plant several foreign grasses, reputed to be heavy nitrogen feeders, on high nitre soils with the expectation of securing some crop which can utilize the nitrogen.

In order that the reader can have a more definite idea of the amount of nitrates which have been found in some of these once arable soils, I am giving below a few figures on this point which have been furnished to me by Dr. Headden, to whom I am indebted for the soil analyses and many of the soil histories contained in this bulletin.

By way of comparison, I may say that an average amount of nitrate for our cultivated fields is from .000626 to .002005 per cent.

TABLE No. 1. Nitrates in certain Nitre Soils.

Source	Material examined	Percent water soluble	Percent nitrates in water soluble	Percent nitrates in air dried soil
Black spot in barley field.	Surface soil two inches	13.4	41.859	5.628
Young orchard	Surface soil	22.466	29.114	6.54
Young orchard	Surface soil two inches	8.23	8.173	.673
Alfalfa field	Top soil five inches	7.78	33.06	2.571
Oat field	Surface soil two inches	5.42	50.221	2.722
Orchard	Top soil 12 inches	6.51	43.57	2.837
Corn and rye.	Surface soil	4.67	7.352	.342
Old orchard	Surface soil	6.65	5.746	.382

These figures may mean more when I say that one of the above samples, which carried 2.873 per cent of nitrates in the surface foot, contained nitrates corresponding to 113,480 pounds, or 56.74 tons per acre foot; in another sample, taken to a depth of five inches, the area involved being about eight acres, sodic nitrate corresponding to 344,000 pounds or 172 tons was found in the surface five inches; in the top four inches of another eight acre tract, the equivalent of 189,971 pounds or 95 tons was found.

With such quantities of nitre in the soil as these figures indicate, it seems hardly necessary to look elsewhere for an explanation of the death of our trees and crops.

Because of other investigations which were already under way, I was not able to take up this very interesting question until recently, except to go on occasional, hurried field trips into the districts involved. Here, I saw all that had been described to me, and, I must confess, intensified and more serious than I had imagined.

A very natural explanation for the accumulation of these nitrates, and one which may have suggested itself to the reader, would be the

concentration of the salts from the irrigation and ground waters in the surface layers of the soil. This, of course, presupposes the existence of a nitrate bearing stratum from which to derive this salt. In the first place, no such stratum or bed is known to exist within the state or neighboring states, and, in the second place, our deep well waters, ground waters and surface waters contain an insignificant and negligible quantity of nitrate.

That these spots are the remains of great herds of extinct animals which perished from some unknown cause is highly improbable, first, because the areas involved are too great; second, as mentioned before, the present spots are increasing in size, and, third, spots are appearing today in localities where the trouble has never been reported before.

For the same reasons, there is no ground for believing that these areas are nitre beds related to some established geological horizon.

Unable to account for this phenomenon satisfactorily in any of the foregoing ways, we have been forced to the one remaining possibility, namely, the formation of the nitrates *in situ*.

Having reached this conclusion only after a thorough study of all other possible causes, Dr. Headden presented the question to me as a purely bacteriological problem, amenable to bacteriological methods.

Under ordinary circumstances, I should have looked to the ammonifying and nitrifying flora of our soils as the responsible agents, but the amount of organic matter in our soils, both cultivated and virgin, is far too small to supply the organic nitrogen required for the manufacture of such quantities of nitrate. Confronted by this nitrate monstrosity on the one hand, and by the dearth of nitrogen on the other, I must confess that the question was somewhat perplexing. However, it seemed to me that the logical method of procedure was to look elsewhere than to the soil for a source of nitrogen. Quite naturally, I turned my attention to the atmosphere.. If it could be demonstrated that our soils had the power of fixing atmospheric nitrogen through the agency of Azotobacter and did fix it, I felt reasonably certain that it was only a question of time until we could show that the ammonifying and nitrifying organisms were utilizing this new supply of nitrogen to build up nitrates.

With this as a starting point, I have begun my studies on the fixation of nitrogen by Azotobacter in certain Colorado soils.

SCOPE OF PRESENT WORK.

Our studies on the fixation of atmospheric nitrogen, presented herein, have not been confined to fixation in solutions alone, but have been extended to include fixation in the soil itself. Two such soil experiments are reported here, but the greater part of this data has been reserved for another bulletin.

Extended studies on the ammonifying and nitrifying efficiency of these same soils are in progress at the present time, the results of which will constitute the text for a future publication.

General Methods.

For determining the nitrogen fixing power of the different soils in solutions, we have used the mannite solution recommended by Lipman[1] except that the tri-basic potassium phosphate, (K_3PO_4), has been substituted for the di-basic, (K_2HPO_4).

Mannite Solution for Nitrogen Fixation.

Tap water	1000.00	c. c.
Mannite	15.00	grams
K_3PO_4	.5	grams
Mg SO_4	.2	grams
Ca Cl_2	.02	grams
10 per cent solution Fe Cl_3	1	drop

This was made neutral to phenolphthalein with normal NaOH. 100 c.c. of this solution containing 1.5 grams of mannite were employed for each soil examined. It was placed in 500 c. c. Erlenmeyer flasks and sterilized in the autoclave for five minutes at 120 degrees C. These solutions were inoculated with 20 c.c. of the given soil infusion corresponding to 10 grams of the soil. The infusion was prepared by mixing 150 grams of soil with 300 c.c. of sterile physiological salt solution (.75% Na Cl), shaking the mixture for five minutes and then allowing it to stand for thirty minutes for the coarser particles to subside, after which the inoculating suspension was withdrawn with a sterile pipette. Four flask cultures were prepared from each soil, two of which were analyzed for total nitrogen immediately, and the remaining two after thirty days' incubation at 28 degrees C.

For isolating and growing our stock cultures we have employed a mannite agar of the same composition as the mannite solution with the addition of 15 grams of agar per 1000 c.c. of solution.

In isolating Azotobacter from the crude soil cultures we have depended solely upon repeated plating for obtaining cultures in a pure condition. We were troubled a great deal with a small bacillus which was almost invariably associated with the Azotobacter colonies in the original plates but by replating through three dilutions, sometimes three different times, we were able to obtain pure cultures. The intermediate glycerine solution recommended by Lipman did not prove satisfactory in our hands.

Our stock cultures of Azotobacter were isolated in March, 1910, and have been transferred every fourteen days since that time on mannite agar.

For determining the total nitrogen in the cultures and in the soils, we have used the Gunning Method modified to include nitrates as described in the Official Methods of Analysis,[2] page 8.

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1. Rept. of Soil Chemist and Bacteriologist, New Jersey Exp. Sta. 1908, p. 137
2. Bulletin No. 107 (Revised) Bureau of Chemistry, U. S. Dept. Agr. 1908.

DISCUSSION OF THE SOILS UNDER STUDY.

NITROGEN FIXING POWER IN SOLUTION.

In order that the reader may have a truer appreciation and a clearer conception of the actual conditions as they exist in the soils about to be described, it has seemed desirable to the writer to accompany each with a brief description of the field or orchard from which the sample was obtained. In several instances, the quantity of nitrate found appears to be in excess of all reason, but when measured by the damage done to vegetation, it falls easily within the limits of possibility. The converse of this proposition is equally true. If we are to witness the destruction of a forty-acre orchard in one season, we shall need to look for some such powerful agent as nitre occurring by the tens of tons to the acre foot.

SAMPLES NOS. 1, 2, 3, 4.

It is needless to say that at the beginnig of our work we encountered unforeseen difficulties. We were dealing with soils which were decidedly unlike other soils, and in which previously unheard of conditions maintained. Naturally, our first samples were taken from those spots where the trouble was unmistakably present, and there was nothing to tell us how concentrated the nitrates might become and still permit the growth of the soil flora. The results obtained with these early samples were rather disappointing inasmuch as they seemed to possess practically no nitrogen fixing power when tested out in mannite solutions. Subsequent work, however, showed that the nitrogen fixing bacteria, as well as the higher forms of plant life, had been destroyed by the nitrates.

After a little experience we were able to establish, in a general way, a relation between the appearance and the nitrate content of a soil, on the one hand, and the probable occurrence of Azotobacter on the other. This made it possible to take samples more intelligently and to avoid the extremely high nitre areas. Samples 1, 2, 3 and 4 will serve very nicely to illustrate the relation of nitrate accumulation to the presence of the nitrogen fixing bacteria. They were collected September 21, 1909.

All four of these were taken from a forty-acre tract, twenty acres of which had been in bearing orchard and the remainder in alfalfa. In 1907 barren spots began to appear in the alfalfa; brown patches, here and there, in the orchard soon became conspicuous, and the trees commenced to die. By 1909, fifty per cent of the orchard had perished along with the entire twenty acres of alfalfa, and in 1910, portions of possibly six rows along one edge and a few trees in a far corner were making their last struggle. The whole center was a barren waste with not a weed to be seen. The greater part was brownish black on the surface, glistening with crystals and to all appearances wet, but, in fact, covered with a hard, dry crust about 3-16 inches thick. Beneath this, the next 1½ to 3 inches were mealy in

character, a mixture of soil and crystals. Below this, the soil grew wet very rapidly and at sixteen inches was practically mud. There was no free water at three feet and in a nearby excavation which had been made for a cellar, over three feet deep, there was no water, yet the soil which varied from a sandy loam to a calcarious clay was decidedly wet and sticky sixteen inches below the surface. It was necessary to dig to a depth of six feet to reach the flow of ground water.

Sample No. 1 was composed of the surface crust of which 12.523 per cent was soluble in water. 19.822 per cent of this, or 1.482 per cent of the air dried soil consisted of nitrates. The flask culture did not develop a typical brown Azotobacter membrane, but rather a whitish yellow scum. This was composed mostly of rod shaped organisms with scattering Azotobacter like forms which disappeared with age. A marked gaseous fermentation of the culture solution took place, accompanied by formation of acetic acid. In thirty days, this soil fixed 1.05075 m. g. of nitrogen.

Sample No. 2 came from the mealy layer beneath the crust; 8.44 per cent of this was water soluble, 15.421 per cent of which or 1.301 per cent of the air dried soil was nitrates. A very delicate, white scum with almost no growth in the body of the liquid was all that was obtained in the culture. There was some fermentation and slight acid production with the odor of butyric ether. In thirty days, the increase in nitrogen was so small as to be practically negligible, being only .5604 m.g.

Sample No. 3 consisted of the twelfth to fourteenth inch inclusive where the ground was wet. Unfortunately I do not have the analysis of this portion of the soil, but in a nearby orchard the fourth to fifteenth inch inclusive contained .676 per cent nitrates. In all probability, my sample carried less than this since it contained a smaller amount of the rich surface material. With this, I secured the Azotobacter forms in a limited number, comparatively speaking, along with the ordinary rods which made up the patchy film and flocculent growth of the culture. Some fermentation and slight acid production with a cheesy odor were observed. An increase of 3.43245 m. g. of nitrogen was obtained after thirty days.

Sample No. 4 came from near a tree along the edge of the affected area. The soil appeared normal and the few trees close by seemed in a healthy condition. The surface two inches were removed and the second to sixth inch inclusive were collected. A typical chocolate brown, wrinkled Azotobacter membrane was obtained with this material in five days. This form was very abundant and dominated in the culture which was slightly acid and possessed an earthy odor. After thirty days, the determination of nitrogen showed an increase of 12.4689 m. g.

A comparison of the results obtained with these four samples suggests that the nitrates were so abundant in the first two that the Azotobacter had either been destroyed or so weakened in virulence that

little or no fixation could be accomplished; that the fourteenth inch sample, while rich in nitrates, did not carry enough to inhibit entirely the growth of the nitrogen fixing bacteria, and that in No. 4, the conditions were very favorable for these organisms.

SAMPLE NO. 5.

This sample was procured September 21, 1909, from an orchard between the irrigating furrows. The brown surface soil, a light clay loam, was removed and a section, including the second to sixth inch, was taken. In 1908 a few of the trees had died and the owner, believing that possibly this had been caused by lack of fertility, had given the orchard a liberal dressing of stable manure. The following spring the ground from which the dead trees had been removed, one to two acres perhaps, along with seven or eight acres of the orchard, was sown to wheat, but to the dismay of all concerned this, too, failed to grow, only a very small per cent ever coming up. During the summer, 1909, fifteen to twenty-year-old trees died by the score, beginning early in the season and continuing late into the fall. A conservative figure for the damage done this year would be the loss of 300 bearing apple trees.

1910 saw a continued spread of the burning, and already in 1911 the attack is being renewed with increased vigor.

In the culture solution, the growth took the form of a dull, almost continuous scum, with patches of white, gelatinous material here and there. There was a slight acid production with the odor of butyric ether at times. The microbic flora consisted principally of large rods, mycelial threads and many clostridium forms resembling closely, if not identical with, Clostridium pastorianum. An increase of 3.0822 m. g. of nitrogen was obtained in thirty days.

SAMPLE NO. 6.

The material for this test was taken from the top of a brown irrigating furrow in a beet field. The surface crust was removed and the next four inches used. The soil was a sandy clay and the field was in alfalfa in 1906. At this time complaints were received of the appearance of bare spots on which the alfalfa was dying out. The largest of these was horse-shoe shaped and about one-half acre in extent. The chief trouble in this instance was seepage but in 1908 the field was sown to oats, and it was not long before a number of brown patches, mealy in character, developed on the higher places. When the land was being prepared for beets in 1909, there was nothing unusual to create one's suspicion except the seepage. I visited the field in September and there were great bare spots surrounded by beets with immense tops. This is shown in Fig. 2, page 13. The stand had evidently been very poor since some of the barren places would average a half acre in area. The soil was mealy and high in nitric acid. That fall the land was sown to winter wheat and when I saw it the next summer, the whole twenty-five acres was a total failure.

My sample was secured in September, 1909, and in thirty days gave a fixation of 3.57265 m. g. of nitrogen. In culture it produced a lemon yellow membrane on the surface with a similar growth in the bottom of the flask. There was a slight acid production accompanied by a butyric, cheesy odor.

Fig. 2. Nitre spot in a sugar beet field. Sample No. 6.

SAMPLES NOS. 7 AND 8.

These samples were taken from a deserted field where the brown areas had become very numerous and extensive. The Russian thistles which had been the last inhabitants of these spots had died and left them bare. Adjoining orchards were suffering from the nitrate burning. The trouble was first noticed here in 1908 and in September of 1909 I took my two samples. No. 6 came from a brown spot, five feet in diameter and No. 7 was taken three feet outside this affected area. In both cases the surface two inches were discarded and the next four inches collected. The soil was a red, gypsiferous clay and no water occurred anywhere near the surface. In culture, these two resembled each other very closely. They produced a yellow membranous growth, with some gas, little acid, and a cheesy odor. No. 7 developed a more typical Azotobacter membrane than No. 8. This was composed largely of the characteristic Azotobacter forms and numerous other small rods and clostridia, but no brown color developed. The membrane produced by No. 8 was not as heavy as No. 7, but was made up of practically the same forms. In thirty days soil No. 7 fixed 3.01215 m. g. and No. 8, 2.87205 m. g. of nitrogen.

SAMPLE NO. 9.

All of the samples which had been collected thus far had been from either high nitre spots or immediately adjoining areas, and it seemed

to me quite desirable that we should have a specimen of soil from some locality where this nitrate trouble had not been heard of. It looked only reasonable that if the nitrates were killing apple trees, they were probably also destroying the microbic soil flora, and I wished to have a sample of what might be considered a normal soil as a check. For this purpose we obtained material from an alfalfa field where there was no history of any trouble. The ground was light, well drained, and judging from the size of the plants, it had been in alfalfa for a number of years. The surface two inches were discarded and the next four inches were taken for the sample.

In ten days a heavy, gelatinous, white Azotobacter membrane formed in the culture flask. Azotobacter was the dominant form, but other small rods were also present. There was some fermentation and an odor of rotten cabbage was developed. After thirty days the membrane was brown in color and had the physical appearance of cold grease which has hardened on top of a beef infusion and later has been disturbed and broken. This soil gave an increase in nitrogen in thirty days amounting to 10.15925 m. g. After obtaining this result and a similar one with No. 4, I felt pretty well satisfied that the true nitrogen fixing power of the soil could not be judged from a sample which was taken from either the dark crust of a nitre spot or an area where all vegetation had been dead for some time and where a chemical analysis showed the nitrates to be extremely high. I felt very confident from our work thus far that some of our soils, at least, were stocked abundantly with Azotobacter chroococcum, but it was very evident that this genus had either been destroyed or become greatly attenuated where the nitrates were excessive. I am inclined to accept the former view by way of an explanation since I have plated out crude cultures repeatedly which were made from very bad soils and have failed to obtain anything which resembled Azotobacter. Again I have had no difficulty at all in isolating pure cultures of Azotobacter from crude cultures prepared from soils which were high in nitrates, but not excessively so, and which a month later developed fatal quantities. After my experience with these two samples, I decided to take the soil for future work from areas where the nitre was just beginning to manifest itself on the vegetation and toward which the wave of nitrate destruction was advancing. I am glad to say that I was not disappointed in adopting this new way of sampling as the following experiments will testify.

SAMPLE NO. 10.

In April, 1910, Dr. Headden called my attention to the unmistakable brown stain on the irrigating furrows of a young orchard belonging to the Experiment Station. This was the first indication of the trouble that had been observed in this immediate vicinity. The color was confined to the furrows, there was no mealy condition of the soil and the trees were in perfect health. The soil was a clay loam, well drained, with gravel and ground water at 18 to 20 feet. Up to the pres-

ent time no injury has been observed in the orchard. The same brown color was very marked along the roadside where the irrigating water had been running three days previously. With this soil taken from the furrow, a yellowish brown membrane, consisting largely of Azotobacter, was obtained, and upon analysis the culture showed an increase of 7.7055 m. g. of nitrogen in thirty days.

SAMPLE NO. 11.

Sample No. 11 was obtained from an alfalfa field located on river bottom land where the water was quite near the surface. Five to ten acres of alfalfa had died and the barren spots were brown to black on the surface. The soil was a light alluvial formation and admirably suited to agriculture. The top four inches were taken for examination June 1910. In culture it developed a heavy straw colored, leathery membrane, after 48 hours, which was composed of Azotobacter cells with many large and small rods. After thirty days, an increase of 5.11365 m. g. of nitrogen was obtained.

SAMPLE NO. 12.

A complaint was received from a certain truck gardener in July 1910, stating that there were places in his garden where, for several years, he had been unable to secure a satisfactory stand. At that time, his chief trouble was with carrots and parsnips. Three to five acres were involved this season, and from the brown appearance of the surface and mealy character to the tread, the soil looked very suspicious. It was a nice sandy loam and no trouble was ever experienced in raising crops except on the barren spots. Even on these, when the plants became once established, they grew very luxuriantly. A sample consisting of the three inches of top soil, taken about ten feet from a barren place, was procured. This yielded a heavy, wrinkled, pale yellow membrane, which browned with age. Azotobacter was abundant and after thirty days our analysis showed an increase of 8.61615 m. g. of nitrogen in the culture.

SAMPLE NO. 13.

We come next to an orchard where the burning first appeared in 1909 on the apple trees. The point of particular interest in this case is the marked resistance which a block of pear trees has shown to the nitre. There are about three acres of these trees in full bearing and, although lying adjacent to a five acre apple orchard which is badly affected, and in the direct path of the nitre streak, the first injured pear tree is yet to be seen. As a matter of fact, this immunity of the pear is an occurrence of rather frequent observation. The apple orchard embraced about seven acres and the trees were all from twenty to twenty-five years old. They had been in perfect condition and yielding abundantly until the summer of 1909 when the burned leaves began to make their appearance. A section in the center of the orchard of about one half acre, succumbed that season, but before July, 1910, when I took my sample, three more acres had died and had been pulled up and the

ground planted to corn. This stand was very poor. Much of it died in the ground shortly after germination, while some that did grow, attained a height of 8 to 10 inches, with sickly yellow leaves and finally died. By the end of fall, 1910, approximately 300 trees had been taken out and consigned to the brush heap and wood pile. I have learned recently that the remaining acre and a half began dying so rapidly this spring (1911) that it, too, was grubbed out. Thus, the complete ruin of the seven acres was brought about in less than two years. The soil is a sandy loam, underlaid with gravel at 5 to 8 feet. There is no water near the surface. The characteristic brown color was plainly visible on the crests and sides of the irrigation furrows and it was from one of these that I took the top three inches of soil for examination. Azotobacter developed readily in culture with the characteristic membrane and after thirty days an increase of 4.13295 m. g. of nitrogen was secured.

SAMPLE NO. 14.

The next sample was procured from an orchard where only a few trees showed signs of firing in the early summer of 1910. I visited this place in July, 1910, and it took considerable diligent hunting to find the few scattering trees which were suffering. There were perhaps twenty in all. Today six acres of this orchard are dead from no other cause than nitre. There was no water at five and a half feet and the soil was a nice clay loam. The sample for the fixation test was taken from between two rows of trees which seemed to be as badly affected as any and included the surface three inches. The ground between the trees had been recently cultivated so that any brown stain which might have been visible on the irrigating furrows had been obliterated. There was no indication of excessive nitrates in the soil other than the burned edges of the apple leaves. Pure cultures of Azotobacter were isolated readily from this soil which gave an increase of 6.65475 m. g. of nitrogen in thirty days.

SAMPLE NO. 15.

While looking over the orchard described above I was asked to pass an opinion on some apricot trees in a neighboring orchard. They were large trees, seven in number, and affected in a most peculiar way. The foliage of the entire tree was wilted as if the water supply was cut off; the leaves had a good green color and there was a heavy set of fruit which was just beginning to ripen. A short distance from the trees, I discovered the brown color on the soil which we have come to regard as an important symptom of the nitre trouble. I set about at once to look for signs of this on the apple foliage nearby, and before I had gone far, my search was rewarded. The number of trees involved was limited to possibly a dozen and these were not burned severely. However, by the end of the season, all of these had died and were taken up, leaving about a quarter of an acre barren. There was some indication of too much water in this orchard and it is very possible that the

question of seepage should be taken into consideration here as well as the high nitrates.

A sample, taken near one of the apple trees, showed the soil to be a rather heavy clay loam. In culture it developed a characteristic white, gelatinous Azotobacter membrane and in thirty days gave a nitrogen increase of 10.15725 m. g.

Sample No. 16.

With Azotobacter as widely distributed as the foregoing sample indicated, there came the natural query, whether this genus was not indigenous to all of our soils in a raw state as well as cultivated. To determine this point I procured my next sample July 13, 1910, from the top of an adobe hill which was above all ditches and consequently was watered only by the scant rainfall. No vegetation was growing here and because of its location and inaccessibility, I have my doubts whether man had ever trod that particular soil before. It was literally raw land in the process of formation. The underlying decomposing shale from which the shallow soil was being made came to the surface in a number of places. The culture solution which was inoculated with an infusion of this material showed only a very slight growth, visible as a slight turbidity and delicate scum. In fact, this may have been due to the infecting substance itself. Microscopic examinations of the solution were made at frequent intervals but nothing which resembled Azotobacter could be detected at any time. After thirty days, there was a slight apparent increase in the nitrogen content of the culture but this was so very small, amounting to only .2802 m. g. that it could be easily accounted for by the personal equation. It was clear from the result obtained here that this virgin soil, at least, possessed neither nitrogen fixing power nor nitrogen fixing flora.

Samples Nos. 17 and 18.

After testing sample No. 16 and finding that it was practically inert so far as nitrogen fixing power was concerned, we were interested in learning what effect cultivation might have upon such a soil since many of the orchards which have been in cultivation from 15 to 20 years were set out in soil similar to this adobe shale. What is more, it is in those older orchards which have been irrigated longer and cultivated more vigorously that we find the nitre trouble making the most rapid progress. If possible, we wanted to get a soil sample from a young orchard recently set in raw adobe shale, where there had been but a limited amount of cultivation. We were fortunate in securing just such a case. At a distance of perhaps a mile from the adobe hill from which sample No. 16 was taken we found a piece of raw land which had been broken for the first time in the fall of 1909 and set to young apple trees in the spring of 1910. This was watered by a high line ditch in which the water had not been superabundant and consequently it had received but little irrigation, and that during only one season. About the only difference between this land and the adobe

hill was the difference in the physical condition brought about by cultivation to conserve the moisture. Two samples were taken, Oct. 26, 1910, from this orchard, one (No. 17) from between the rows of trees well out in the tract, and the other (No. 18) from a ditch bank where the moisture conditions should have been more favorable for the growth of the soil bacteria. In culture, neither of these soils produced any surface film and gave only a thin, white membrane in the bottom of the flask. The nitrogen determinations after thirty days indicated that the soil from the ditch bank had actually lost nitrogen while the increase with the other was so slight as to be negligible, (.35025 m. g.) If any conclusion can be drawn from the examination of samples Nos. 16, 17, 18 it would seem to indicate that our adobe shale soils both in the raw state and during early cultivation lack nitrogen fixing powers.

SAMPLE NO. 19.

The next sample was taken July, 1910, in a bearing orchard where the burning had appeared for the first time the previous year. There was no well defined area in which one could say that the trouble was worst but it was scattered throughout. In all, about two and one-half acres had been killed when I visited the ranch. The soil is a sandy loam which cultivates beautifully. It is underlaid with gravel at five and a quarter feet in whch there is a little water at times. A hole six feet deep was dug in this orchard and allowed to remain open for one year for the purpose of seeing if there was an excess of water in this soil which could be removed by proper drainage. At the end of the time stated, the hole was as dry as the day it was put down. The brown color was plainly visible on the sides and crests of the irrigation furrows and the trees were dying in a manner that we have come to recognize as specific for nitre burning. The sample from this orchard was taken from between the irrigating furrows near a tree that was just beginning to burn. In culture, there developed a heavy gelatinous, white, wrinkled membrane with scattered brown patches. Abundant Azotobacter cells were present. After thirty days, it showed an increase of 9.807 m. g. of nitrogen.

SAMPLE NO. 20.

Although I felt reasonably certain at the outset that we would secure little, if any, fixation with this soil, I was interested in learning whether, when an orchard died in a phenonemally short time, as was true here, the Azotobacter were likewise killed. There were about thirty acres altogether in the orchard, fifteen of which died between June, 1909, and July, 1910. Sample No. 20 was taken from that section which had been destroyed in 1909 and which had received no water during 1910 so that by July the surface was very hard and dry. The soil varied from a sandy loam to a clay loam with no water at six feet. In culture, a delicate, white, membranous film was formed on the surface with some flocculent growth in the liquid. A sour, earthy odor was developed. The increase in nitrogen amounted to only 2.5218 m. g. in thirty days, demonstrating again that the concentration of the

nitrates, which had proven disastrous to the trees, had also had its detrimental effect upon the nitrogen fixing flora.

Sample No. 21.

This sample, a red sandy loam, was taken in an orchard, July 1910, where the conditions were much the same as those described for No. 20. The orchard included about two acres along one side of which ran a twenty foot wash so that every chance for good drainage was afforded. The trees had begun dying here in 1910 and were about all gone by late summer. The soil was brown along the ditch banks and irrigating furrows. In culture a moderately heavy, white film, containing Azotobacter, formed on the surface of the medium and there was some butyric fermentation. The increase in nitrogen after thirty days amounted to 2.8014 m. g.

Sample No. 22.

In this sample we have one of the most severe cases of nitrate destruction which we have ever recorded. Here is a 90 acre orchard which showed the first symptoms in 1908, and today at least forty-five acres are entirely dead or will be by fall. The soil varies from a red clay to a sandy loam and there is no water at five feet. When sampled late in July, 1910, scattering trees were badly affected, but many were showing only a few burned leaves on the water sprouts. The irrigating furrows showed a light brown stain, more especially on the crests than along the sides, since the orchard had been irrigated recently and it was rather difficult to distinguish the brown color from the moist conditions of the furrow. There was little doubt at this time that the trees were in a very dangerous condition but it was hardly expected that in less than a year half of the tract with its fifteen year old apple trees would be waste land. This soil gave a heavy white gelatinous membrane composed mostly of Azotobacter cells and after thirty days the nitrogen of the culture had increased 8.89635 m. g.

Sample No. 23.

We come next to an orchard where the soil is a red clay loam. This is one of the more recent orchards to show the burning and nothing unusual was observed here until July, 1910. At this time very few of the trees were killed outright but many were in the first stages and some were in a very critical condition The area of the orchard was about forty acres and over one half of the trees are dead today. The soil showed almost no brown color when I took my sample, due possibly to the peculiar red color naturally present. I am inclined to believe that at this time the nitrates had not become extremely high or more of the trees would have been killed and we should undoubtedly have seen more of the brown stain. The culture from this sample showed almost no surface growth but a white membrane on the bottom and sides of the flask. Along with this there developed a marked foecal odor. Azotobacter was present in quantity. The increase in nitrogen in thirty days due to fixation amounted to 7.1451 m. g.

SAMPLE NO. 24.

A barley field on the top of a mesa was the next location chosen for our work. This particular tract was selected for several reasons. In the first place, the nitrates had been accumulating here since 1907 and had become so concentrated by this time, July, 1910, that the only place anything would grow was right along the irrigating furrows and even there the grain was very short and thin. Apparently the water in running through these had washed out a little of the nitrate from time to time and so had reduced the salts to a degree of partial tolerance. The soil on top of this mesa, for some reason, is always wet and one not familiar with the topography of the country would be very apt to suggest that the land was seeped by higher irrigation projects. As a matter of fact, this mesa is at least 200 feet higher than the surrounding country and there is no possible chance for seepage in the sense in which the term is ordinarily used. This peculiar condition seems to have resulted from excessive irrigation and a lack of proper drainage. To use a popular expression, the soil has become "water logged." The superabundance of moisture had most certainly favored nitrate production and the agents which were responsible for the coloring matter, for the soil was as black on the surface as crude oil, and as mealy beneath as wood ashes. Before taking a sample, the surface crust and the next two inches were removed and a section, including the fourth to sixth inch inclusive, was obtained. This came from along an irrigating furrow where the barley was making a feeble struggle. In culture, there was almost no surface growth and only a moderate white deposit on the bottom and sides of the flask. A butyric odor was perceptible. I was rather surprised to find that after thirty days there was an increase of 1.68121 m. g. of nitrogen in the culture.

SAMPLE NO. 25.

As a source for the next sample, I selected a truck garden on the outskirts of a mining town. This was thirty-six miles from the nearest case of nitre trouble of which I had knowledge, and so far as I could learn nothing of the sort had ever been observed here either on the soil or the vegetation. The soil chosen was a very light, deep sandy loam which from its proximity to the river, I took to be of alluvial formation. All kinds of vegetables, together with strawberries, were grown here very successfully. The culture produced with this soil gave a heavy gelatinous membrane, light brown in color, and was made up almost entirely of Azotobacter. The increase in nitrogen in thirty days amounted to 5.8842 m. g.

SAMPLE NO. 26.

Sample No. 26 represents the soil of a young orchard in which several of the small trees on the high ground had died in 1910 and others were looking very suspicious. The ground was first broken in the fall of 1908 and set to apples in the spring of 1909. It was irrigated and cultivated thoroughly that season and had been irrigated for the third

time in 1910 when I took my sample Oct. 25. The soil is a clay loam with considerable gravel, in good condition, and so far as I could observe there was no brown color visible although this had been reported as occurring earlier in the season. The land sloped well so there should be ample opportunity for drainage. When introduced into mannite solution, an infusion of this soil produced a heavy, wrinkled surface membrane, with scattering brown patches, the growth being almost exclusively Azotobacter. The increase in nitrogen in this culture was 14.7105 m. g. in thirty days.

Sample No. 27.

The material for the next study was obtained from an orchard where evidence of nitre was observed for the first time in the summer of 1910. This was an old orchard and a number of the largest trees were very badly injured but not yet dead. There was no indication of the trouble other than the firing of the green leaves. In an adjacent orchard, there had been heavy loss the previous year and all signs pointed to a repetition of the disaster for 1910. The soil was a heavy clay and my sample consisted of the surface two inches taken between two of the affected trees. The culture obtained from the soil infusion of this soil yielded a heavy, wrinkled, surface membrane with isolated brown patches. The increase in nitrogen in the culture in thirty days amounted to 11.3481 m. g.

Sample No. 28.

The next sample was taken from what had been a young orchard three years previously. It had been given the best of care which may have hastened the appearance of the destroying agents. The tract contained approximately twenty acres sloping gently to the south and west. Some years before it was set to orchard, a reservoir had been built on the northeast corner, the highest point on the place. This was not a success since it was producing a seeped condition in the lower surrounding country and it had to be abandoned. This was about four years before the orchard was planted. The soil is a clayey loam, for the most part, underlaid with a shale. In 1908 the mealy nature of the surface was first observed. At this time Dr. Headden took a sample and states that the conditions did not afford an opportunity for him to judge the color. I have visited this orchard two different times since then and it has so happened each time I have been there that the soil either has been so extremely dry that no color was visible or else it had just been cultivated and all traces on the irrigating furrows had been obliterated. Four acres of the young orchard died in the spring of 1909 and by fall the area involved had nearly doubled. In Oct., 1910, there were scarcely three acres of the original twenty alive. The living trees were all to be found in the five or six rows along the highest side of the tract. When the first injury appeared in 1909, we learned that this same four acres had given trouble in former years, when the land was in alfalfa, so it was to be expected

that this part of the young orchard would be the first to go. As fast as the trees died they were taken up and in 1910 at least twelve acres were sown to corn. Only a very small per cent of this ever reached a height of eighteen inches, and much of it never came through the ground. All over the area involved there are great barren spots, some of them a half acre in extent, where not even a Russian thistle will grow. A two inch surface sample was taken from one of these spots, October 29, 1910, and contrary to expectation my culture developed a yellowish surface membrane with brown patches. Azotobacter was very plentiful. After thirty days the culture showed an increase of 8.6862 m. g. of nitrogen. Inasmuch as all vegetation had refused to grow where the sample was collected, I had rather imagined that the Azotobacter would be killed out as well, and was not anticipating any such active fixation as was secured.

SAMPLES NOS. 29, 30 AND 31.

The next orchard presents, without exception, the most severe case of nitre that has been called to our attention; severe not only in point of destruction, but in rapidity of spread as well. We have seen orchards where the isolated trees and parts of rows were scattered over a large area, but nowhere else have we observed one solid row after another, the entire length of the orchard, go down in rapid succession, as clean as before a forest fire. The original orchard covered about 15 acres of ground sloping gently to the south and, as measured by its producing capacity, was in excellent condition up to the winter of 1909-1910. At this time a spot about twelve feet in diameter appeared at the lower edge of the tract, which the manager stated always looked wet and black in color. Little attention was paid to this until the spring of 1910 when the trees in this vicinity began dying as with nitre. The trouble spread rapidly up hill and back into the orchard so that by the end of the summer 1910 two and one-half acres had been killed and approximately two acres had been taken up.

I visited the ranch on Oct. 29th and found the barren area very wet and boggy in places. The mud was exceedingly sticky and so soft in spots that one would sink down ankle deep in walking over it. Such spots were usually dark brown or black in color and a little higher than the adjacent ground on which a deposit of white alkali had formed following a light snow. I was told that this was the first time the white alkali had been in evidence. The greater part of the barren area was white except for isolated elevated patches and a strip twelve to fifteen feet wide along the upper side which was black. All indications seemed to point to the fact that the portion occupied by the white salts was too wet for the development of the black pigment. That the reader may have some conception of the violence of the attack, I may say that plum trees were pointed out to me which three weeks before were in perfect condition and now were absolutely dead. For four rows back from the edge of the barren area the trees were either

dead or dying (See Fig. 3, Page 23) and beyond these the burning seemed to stop. However, twelve rows farther back on the higher ground I discovered a single tree which was firing. There was a little white alkali nearby but no sign of any brown or black color. I took Sample No. 29 from the surface of the soil near this tree. So far as I could see, this was the only tree in that part of the orchard which was suffering at this time. I visited this same spot January 31, 1911, and the spectacle that greeted me was awful, to express it mildly. Where three months before there was but a single tree affected, there

Fig. 3. Section of an orchard killed by nitre. Photographed October 29, 1910.

were now six to eight acres involved. The soil was brown and very mealy. The orchard manager informed me that most of this change had followed the last irrigation of the orchard which was given about December 1, 1910. He related that three or four days after he had finished irrigating, he noticed a dark brown, oil-like spot ten inches in diameter near the tree from which sample No. 29 was taken and that after twenty-four hours this had increased to twenty-four feet in diameter by actual measurment. In spite of all efforts to break down this testimony by cross examination and conservative suggestions, my informant held firmly to the original statement declaring that there was absolutely no exaggeration. This particular instance most certainly holds all previous records for rapid progress. It was

Fig. 4. Apple tree killed by nitre. Photographed October 29, 1910.

Fig. 5. Healthy apple tree located 100 feet from the tree shown in Fig. 4, and photographed on the same day.

from this spot as a focal center that the malady had spread so as to involve eight acres in an entirely new part of the orchard. On April 18, 1911, I looked over this proposition again. There was not a shadow of a doubt in my mind but that the whole fifteen acres were destined to go sooner or later. A conservative figure of the loss up to this date was thirteen acres and the balance were dying. The property had changed hands three times since my first acquaintance with it and the present owner, believing that drainage would relieve the difficulty, expended over $4000 in putting in some 15,000 feet of drain tile. Some little water flows from this drain but as far as ameliorating the condition of the orchard, there seems to be practically no change. Sample No. 30 was taken from one of the black, wet spots mentioned. Since these were of very recent appearance I was interested in knowing whether this intense black color was necessarily an indication of the concentration of the nitrates. On the one hand, if that was true, I should expect to get only a very slight fixation of nitrogen in the culture; on the other hand, if it bore no immediate relation to excessive quantities of the salt, then I would look for larger results.

Sample No. 31 was collected by Dr. Headden, January 5, 1911, from the eight acre section where the nitrates had developed very rapidly since December, 1909. When he handed me the material, he remarked that he would not be at all surprised if I got no results from this soil for it was as brown and mealy as could be. In culture solution all three of these samples gave typical brown, wrinkled surface membranes which a microscopic examination showed to be rich in Azotobacter. With No. 29, taken from near the single affected tree, the increase in nitrogen in thirty days amounted to 10.2273 m. g.; with No. 30, from the black spot, 10.15725 m. g. and with No. 31, 7.9857 m. g. The result from No. 30 would seem to indicate that the black color does not necessarily mean extremely concentrated nitrates. (Figs. 1, 4 and 5.)

Sample No. 32.

The next sample was taken October 29, 1910, along the road side near the fence, where the soil looked mealy but where there was no discoloration, which could be accounted for probably by the dry condition of the soil. This spot was selected because the road mentioned ran alongside a young orchard where the trees had been dying from some unknown cause. There was such a combination of factors at work in the orchard, namely, neglect, drought and possibly nitre that it was hardly safe to venture an opinion on the cause of the death of the trees. An alfalfa field adjoining this tract showed many barren spots which were suggestive at least. In culture, this soil developed a heavy, tough, brownish membrane, rich in Azotobacter and after thirty days gave an increase of 15.411 m. g. of nitrogen.

TABLE No. 2. Summary of Nitrogen Fixing Power of Soils, Numbers 1 to 32, in Mannite Solution.

Sample No.	Source	Date of Collection	Date of Examination	Date of Completion	Milligrams Nitrogen at beginning	Milligrams Nitrogen at end	Milligrams Nitrogen fixed per 1.5 grams Mannite, 30 days
1	Orchard—surface crust ¼ inch	Sept. 21, 1909	Oct. 5, 1909	Nov. 4, 1910	4.48320	5.53395	1.05075
2	Orchard—4th to 6th inch	Sept. 21, 1909	Oct. 5, 1909	Nov. 4, 1909	.84060	1.40100	.56040
3	Orchard—12th to 14th inch	Sept. 21, 1909	Oct. 5, 1909	Nov. 4, 1909	.77055	4.2030	3.43245
4	Orchard—surface removed 2nd to 6th inch	Sept. 21, 1909	Oct. 5, 1909	Nov. 4, 1909	1.12080	13.5897	12.46890
5	Orchard—surface removed 2nd to 6th inch	Sept. 21, 1909	Oct. 5, 1909	Nov. 4, 1909	.98070	4.06290	3.08220
6	Beet field—irrigating furrow, 2nd to 6th inch	Sept. 22, 1909	Oct. 5, 1909	Nov. 4, 1909	1.75115	5.3238	3.57265
7	Deserted land—barren spot, 2nd to 6th inch	Sept. 24, 1909	Oct. 5, 1909	Nov. 4, 1909	3.08220	6.09435	3.01215
3	Same as No. 7—outside barren spot, 2nd to 6th inch	Sept. 24, 1909	Oct. 5, 1909	Nov. 4, 1909	3.0822	5.95425	2.87205
9	Alfalfa field—normal, 2nd to 6th inch	Sept. 24, 1909	Oct. 5, 1909	Nov. 4, 1909	1.54110	11.69835	10.15725
10	Orchard—edge of irrigating furrow, surface 2 inches	April 26, 1910	April 27, 1910	June 26, 1910	.9807	8.6862	7.7055
11	Alfalfa field—surface 4 inches	June 24, 1910	June 27, 1910	July 27, 1910	3.43245	8.5461	5.11365

Sample No.	Source	Date of Collection	Date of Examination	Date of Completion	Milligrams Nitrogen at beginning	Milligrams Nitrogen at end	Milligrams Nitrogen fixed per 1.5 grams Mannite, 30 days
12	Truck garden—surface 3 inches	July 4, 1910	July 4, 1910	Aug. 3, 1910	5.39385	14.01	8.61615
13	Orchard—surface 3 in. from irrigating furrows	July 13, 1910	July 23, 1910	Aug. 22, 1910	.63045	4.76340	4.13295
14	Orchard—surface 3 in. from irrigating furrows	July 13, 1910	July 23, 1910	Aug. 22, 1910	.07005	6.72480	6.65475
15	Orchard—surface 3 in. from irrigating furrows	July 13, 1910	July 23, 1910	Aug. 22, 1910	.35025	10.50750	10.15725
16	Raw land from adobe hill—surface 3 inches	July 13, 1910	July 23, 1910	Aug. 22, 1910	.00000	.28020	.28020
17	Young orchard on adobe shale—surface 2 inches along ditch.	Oct. 26, 1910	Nov. 9, 1910	Dec. 9, 1910	1.33095	.7005	0.0000
18	Same as No. 17—surface 2 inches between trees	Oct. 26, 1910	Nov. 9, 1910	Dec. 9, 1910	.49035	.8406	.35025
19	Orchard—surface 3 in. between irrigating furrows	July 1, 1910	July 23, 1910	Aug. 22, 1910	.4203	10.22730	9.80700
20	Orchard—surface 3 in. between trees	July 16, 1910	July 23, 1910	Aug. 22, 1910	.70050	3.22230	2.52180
21	Orchard—surface 2 in. from irrigating furrow	July 14, 1910	July 23, 1910	Aug. 22, 1910	.28080	3.08220	2.80140

TABLE No. 2, (Continued). Summary of Nitrogen Fixing Power of Soils, Numbers 1 to 32, in Mannite Solution.

Sample No.	Source	Date of Collection	Date of Examination	Date of Completion	Milligrams Nitrogen at beginning	Milligrams Nitrogen at end	Milligrams Nitrogen fixed per 1.5 grams Mannite, 30 days
22	Orchard—surface 2 in. from irrigating furrow	July 14, 1910	July 23, 1910	Aug. 22, 1910	.21015	9.10650	8.89635
23	Orchard—surface 3 in. between irrigating furrows	July 16, 1910	July 23, 1910	Aug. 22, 1910	.35025	7.49535	7.14510
24	Barley field—black surface 3 inches near irrigating furrow	July 20, 1910	July 23, 1910	Aug. 22, 1910	.35025	2.03146	1.68121
25	Truck patch—normal, surface 3 inches	July 21, 1910	July 23, 1910	Aug. 22, 1910	.42030	6.30450	5.88420
26	Young orchard—surface 3 inches	Oct. 26, 1910	Nov. 9, 1910	Dec. 9, 1910	.2802	14.9907	14.7105
27	Orchard—surface 3 inches	Oct. 26, 1910	Nov. 9, 1910	Dec. 9, 1910	.4203	11.7684	11.3481
28	Young Orchard—surface 3 inches	Oct. 26, 1910	Nov. 2, 1910	Dec. 2, 1910	.35025	9.03645	8.68620
29	Orchard—surface 2 inches	Oct. 29, 1910	Nov. 2, 1910	Dec. 2, 1910	.4203	10.6476	10.2273
30	Same as No. 29—surface inch of black spot	Oct. 29, 1910	Nov. 2, 1910	Dec. 2, 1910	3.29235	13.4496	10.15725
31	Same as No. 29—mealy surface 3 inches	Jan. 5, 1911	Jan. 6, 1911	Feb. 5, 1911	.49035	8.47605	7.98570
32	Orchard roadside—mealy soil under [illegible]	Oct. 29, 1910	Nov. 2, 1910	Dec. 2, 1910	.4203	15.8313	15.4110

While it may be early to state any conclusions, even tentatively held, the foregoing work suggests the following:

1. Excessively high nitrates in the soil will kill the Azotobacter flora.

2. A limited amount of soil nitrate does not seriously affect the nitrogen fixing power of a soil.

3. Our adobe shale soils, both in the raw state and when newly cultivated, possess little if any nitrogen fixing power.

4. The nitrogen fixing power of our soils is not limited to any geographical locality or class of soils, however, the degree of activity may vary.

5. The power to fix atmospheric nitrogen is a property common to many cultivated Colorado soils.

6. Azotobacter chroococcum appears to be the dominant nitrogen fixing agent.

THE NITROGEN FIXING POWER OF SOILS IN SITU.

Having satisfied ourselves that certain Colorado soils possessed the power of fixing atmospheric nitrogen in solutions, the next point on which we wished to inform ourselves was whether these same soils had the power of fixing nitrogen *in situ.* If that could be demonstrated, it would be a relatively simple matter to explain the high nitrates, for, given the proteid nitrogen from which to make the nitrates, we felt reasonably certain that the ammonifying and nitrifying flora would take care of the conversion.

For this part of the investigation two samples of soil were selected at random, one from the central part of the state, and the other from the northern. Both were from localities where either the nitre trouble or the brown stain had been observed. The nitrogen fixing power of these soils was determined independently by two different workers, the northern Colorado sample by Dr. Headden, and the central by the writer. The soils were not handled in the same way by the two of us, so it may be well to discuss our respective manipulations. Other soils have been studied but these two are of particular interest since the results were obtained independently in different laboratories.

Northern Sample.

This soil was collected by Dr. Headden, December 12, 1910, from the young orchard designated as No. 10 in the preceding series. It was screened in a moist condition through a twenty-five mesh wire screen and 1200 grams of the moist soil, with no further treatment, were placed in a deep culture basin (10 in. x 2 in.) and pressed down firmly. The soil moisture was determined and sufficient boiled distilled water was added to make eighteen to twenty percent moisture. This was maintained throughout the experiment. The soil was incubated for twenty-seven days in the dark at 28°C. to 30°C. at the end

of which time samples were removed for analysis and the total nitrogen determined. This showed a gain of 10.54 m. g. of nitrogen per 100 grams of soil for the 27 days.

I am indebted to Dr. Headden for the following results:

Total nitrogen at the end of 27 days -	117.79 m. g. per 100 g. soil.
Total nitrogen at the beginning, -	107.25 m. g. per 100 g. soil.
Total nitrogen gained by fixation in 27 days, ----------------------	10.54 m. g. per 100 g. soil.

Assuming that the fixation, under field conditions, proceeds uniformly at this same rate for six months, it would mean an addition of 475.26 pounds of nitrogen or 2,970.41 pounds of protein per month for every acre foot, and in six months, this would amount to 2,851.60 pounds of nitrogen or 17,822.50 pounds of protein, while in a year, we should have 5,703.20 pounds of nitrogen or 35,645.00 pounds of protein per acre foot. With this increase of 2.85 tons of nitrogen or 17.82 tons of protein per acre foot in one year, there certainly need be no cause for anxiety over a source of nitrogen for high nitrate formation.

Central Sample.

This soil was collected by the writer December 30, 1910, and was from the same source as the sample designated as No. 29 of the preceding series. The soil was first air dried and then passed through a 40 mesh wire screen. The moisture was determined and found to be 2.1 per cent. Sufficient sterile distilled water was next placed in a deep culture dish (100 m. m. x 30 m. m.) to give 100 grams of the air dried soil a water content of 10 per cent. 100 grams of the soil were next added to the water in the culture dish and the weight of the whole was determined. This weight was kept constant by daily additions of sterile distilled water throughout the experimental period. The soil was incubated in the dark at 28°C. to 30°C. for thirty days at the end of which time samples were removed and the total nitrogen determined. For every 100 grams of soil there was an increase of 8.22 m. g. of nitrogen in thirty days.

Total nitrogen at the end of 30 days, - -	82.11 m. g. per 100 g. soil
Total nitrogen at the beginning, - - -	73.89 m. g. per 100 g. soil
Total nitrogen gained by fixation in 30 days,	8.22 m. g. per 100 g. soil

Considering that the fixation, under field conditions, proceeds uniformaly at this same rate for six months, it would mean an additon of 333.60 pounds of nitrogen or 2,085.00 pounds of protein per month for each acre foot, or in six months this would amount to 2,001.60 pounds of nitrogen or 12,510.00 pounds of protein, while in one year we should have 4,003.2 pounds of nitrogen or 25,020.00 pounds of protein. Expressing this in tons per acre-foot per annum, we get an increase of 2.001 tons of nitrogen or 12.5 tons of protein.

Table No. 3. Summary of Fixation of Nitrogen in Soils in Situ.

Source of Sample	Duration of Experiment	Milligrams nitrogen per 100 g. soil at beginning.	Milligrams nitrogen per 100 g. soil at end.	Milligrams nitrogen fixed per 100 g. soil
Northern Colorado	27 days	107.25	117.79	10.54
Central Colorado	30 days	73.89	82.11	8.22

Table No. 4. Increase in Nitrogen per 100 g. of Soil.

Source of sample	Increase in nitrogen per 100 g. soil as					
	Milligrams nitrogen		Milligrams protein		Milligrams $Na\,NO_3$	
	1 month	1 year	1 month	1 year	1 month	1 year
Northern Colorado	11.88	142.58	74.26	891.12	72.08	865.14
Central Colorado	8.34	100.08	52.12	625.50	50.60	607.26

Table No. 5. Increase in Nitrogen per Acre-foot of Soil.

Source of sample	Increase in nitrogen per acre-foot of soil as					
	Pounds nitrogen		Pounds protein		Pounds $Na\,NO_3$	
	1 month	1 year	1 month	1 year	1 month	1 year
Northern Colorado	475.26	5,703.20	2,970.41	35,645.00	2,883.82	34,605.87
Central Colorado	333.60	4,003.2	2,085.00	25,020.00	2,024.21	24,290.61

Relation of Soil Moisture to Fixation of Nitrogen in Soil.

It has been a matter of frequent observation that where there is an excess of water, as in land which is unquestionably seeped, or where there is a liberal coating of white alkali on the surface, a condition indicative of poor drainage, neither the brown color nor the high nitrates are to be found. However, along the margin of such areas on the higher ground where there is an abundant supply of moisture but not too much, we are apt to find both the high nitrates and the brown color. These two conditions, we have come to associate with the presence of the nitrogen fixing organisms in the soil, and the resulting nitrogen fixing power of that soil. We do not mean to say that they are, by any means, a necessary accompaniment, yet they are very often found together, and from certain experiments which we have made, directed especially toward this feature of the problem, we are led to believe that the relation existing among these three factors is a dependent one.

One step toward the proof of this lay in the demonstration of the relation of the moisture content of the soil to the fixation of nitrogen. To this end, six deep culture dishes were prepared with varying amounts of sterile distilled water each containing sufficient to give 100 grams of air dried soil with a moisture content of 2.1 per cent the following degrees of moisture: 2.1, 10, 20, 25, 30, and 48 per cent respectively. 100 grams of air dried soil which was known to possess nitrogen fixing powers *in situ* were added to each dish. It will be noted that the first dish contained the air dried soil only, while the last, with 48 per cent water, was saturated. The weight of each dish and its contents was determined, and every day the loss of water by evaporation was restored with sterile distilled water. The soils were all kept in the incubator at a temperature of 28°C. to 30°C. for thirty days at the end of which time the total nitrogen was determined for each. The results of the experiment are given in Table No. 6.

TABLE No. 6. Relation of Soil Moisture to Nitrogen Fixation in Soil.

Per cent moisture	Milligrams nitrogen per 100 g. soil		Milligrams nitrogen fixed per 100 g. soil in 30 days
	At beginning	After 30 days	
2.1	73.89	78.84	4.95
10.0	73.89	82.11	8.22
20.0	73.89	80.90	7.01
25.0	73.89	79.13	5.24
30.0	73.89	78.49	4.60
48.0	73.89	73.85	....

The experiment indicates that the optimum moisture content for maximum fixation lies between 10 per cent and 20 per cent; that the amount of fixation gradually decreases as the saturation point of the soil is approached at which it is zero. These results are in perfect harmony with our field observations which have pointed clearly to the detrimental effect of excessive moisture both on the production of brown color and the formation of high nitrates.

THE RELATION OF NITRATES AND AZOTOBACTER CHROOCOCCUM TO THE BROWN COLOR.

The continual occurrence of the brown color on high nitre soils, which have been shown to possess nitrogen fixing power, is too constant an association to be regarded as a mere accident or coincidence. This relation needs no further exposition since it has been referred to repeatedly in the preceding pages, but before entering into any discussion of the subject, it should be understood clearly and emphatically that we have no intention of appealing to the nitrates or the nitrogen fixing flora of the soil to explain *every* brown spot or similar discoloration that may be found. There are at least two other recognized agents that may be responsible for a similar condition. I refer to the

well known Black Alkali of the Southwest in which sodium carbonate is the active principle in bringing the soil humus into solution, which solution, being highly colored, may give the surface a dark appearance. Again there are some soils which contain sufficient quantities of calcium chloride to absorb enough moisture to impart a dark color to the soil. I have Dr. Headden's statement that none of the soils which are concerned in this project contain enough of either sodium carbonate or calcium chloride to account for this phenomenon. Our problem is manifestly different from either of these.

In our pure culture studies of the Azotobacter flora of these soils, we have isolated what appear, in the final analysis, to be six or seven varieties of Azotobacter chroococcum. Three of these, at one time or another, have produced the characteristic brown color on mannite agar. One of these, No. 3, has maintained this character undiminished since it was first isolated; the second, No. 93, acquired the color three weeks after isolation, retained it for six weeks and then lost it; the third, No. 1, has produced a small amount of a light brown pigment at times ever since its isolation but there has been nothing constant in this respect until the last six weeks when it has begun to produce a heavy dark brown color. Three of the remaining four cultures, Nos. 4, 8 and 10, have been characterized by their spreading nature and their abundant, moist, raised, gelatinous, starchy white to yellowish growth on mannite agar. Morphologically and culturally, these three possess such differences as seem to make them distinct from one another; the fourth, No. 13, differed from all the rest in the production of a delicate cream colored pigment; it was spreading in habit but flat, not gelatinous and grew only moderately well on mannite agar. Unfortunately, this culture was lost early in our work, and consequently it has been given no consideration in this treatise beyond mere mention.

The brown color of cultures 1, 3, and 93 served to identify them beyond reasonable doubt as Azotobacter chroococcum. The other four cultures were left unclassified, for the time being, except to place them in the genus Azotobacter after they had been shown to possess nitrogen fixing powers in pure culture.

The close resemblance between the brown pigment formed by some of our cultures and the brown color present on certain soils was suggestive to say the least. It seemed reasonable to me that there might be something peculiar to our soils which could stimulate and intensify the pigment producing power of Azotobacter chroococcum.

To determine this, a number of synthetic agars were prepared, the composition of which was based upon the water soluble salts present in a certain nitre soil. The carbon was supplied in the form of mannite. Each agar differed from every other in the omission of one of the compounds, our object being to determine by elimination, if possible, if any one constituent was directly responsible for the brown pigment. The analysis of the water soluble salts in the soil which was

used as a basis for preparing the different agars, together with the composition of the various solutions from which the agars were made is given below. The solid medium was prepared by adding 15 grams of agar to each 1000 c. c. of solution.

**Water soluble salts in soil used as a basis for synthetic agars.*

	Per Cent
$Ca\ SO_4$	15.902
$Mg\ SO_4$	2.942
$K_2\ SO_4$	3.387
$Na_2\ SO_4$	15.264
$Na_2\ CO_3$	4.813
$Na\ Cl$	34.145
$Na\ NO_3$	22.781
Silicic Acid	.252
Loss (water, organic matter, etc.)	.471

The water soluble amounted to 2.97 per cent of the air dried material.

Solution lacking Calcium Sulphate ($Ca\ SO_4$)

Distilled water	1000.00	c. c.
$Na_2\ SO_4$	9 0668	grams
$Na_2\ CO_3$	2.8589	grams
$Na\ Cl$	20.2621	grams
$Na\ NO_3$	13.5319	grams
$K_2\ SO_4$	2.0118	grams
$Mg\ SO_4$	1.7475	grams
Mannite	15.0000	grams

Solution lacking Sodium Carbonate ($Na_2\ CO_3$)

Distilled water	1000.00	c. c.
$Ca\ SO_4$	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
$Na\ Cl$	20.2621	grams
$Na\ NO_3$	13.5319	grams
$K_2\ SO_4$	2.0118	grams
$Mg\ SO_4$	1.7475	grams
Mannite	15.0000	grams

Solution lacking Sodium Chloride ($NaCl$.)

Distilled water	1000.00	c. c.
$Ca\ SO_4$	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
$Na_2\ CO_3$	2.8589	grams
$Na\ NO_3$	13.5319	grams
$K_2\ SO_4$	2.0118	grams
$Mg\ SO_4$	1.7475	grams
Mannite	15.0000	grams

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*Furnished by Dr. Headden. Bul. 155, p. 17. Analysis XV. Colo. Exp. Sta.

Solution lacking Sodium Nitrate ($Na\ No_3$.)

Distilled water	1000.00	c. c.
$Ca\ SO_4$	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
$Na_2\ CO_3$	2.8589	grams
$Na\ Cl$	20.2621	grams
$K_2\ SO_4$	2.0118	grams
$Mg\ SO_4$	1.7475	grams
Mannite	15.0000	grams

Solution lacking Sodium Sulphate ($Na_2\ SO_4$)

Distilled water	1000.00	c. c.
$Ca\ SO_4$	9.4457	grams
$Na_2\ CO_3$	2.8589	grams
$Na\ Cl$	20.2621	grams
$Na\ NO_3$	13.5319	grams
$K_2\ SO_4$	2.0118	grams
$Mg\ SO_4$	1.7475	grams
Mannite	15.0000	grams

Solution lacking Magnesium Sulphate ($Mg\ SO_4$)

Distilled water	1000.00	c. c.
$Ca\ SO_4$	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
$Na_2\ CO_3$	2.8589	grams
$Na\ Cl$	20.2621	grams
$Na\ NO_3$	13.5319	grams
$K_2\ SO_4$	2.0118	grams
Mannite	15.0000	grams

Solution lacking Potassium Sulphate ($K_2\ SO_4$)

Distilled water	1000.00	c. c.
$Ca\ SO_4$	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
$Na_2\ CO_3$	2.8589	grams
$Na\ Cl$	20.2621	grams
$Na\ NO_3$	13.5319	grams
$Mg\ SO_4$	1.7475	grams
Mannite	15.0000	grams

Solution lacking Mannite ($C_6H_{14}O_6$)

Distilled water	1000.00	c. c.
$Ca\ SO_4$	9.4457	grams
$Na_2\ SO_4$	9.0668	grams
$Na_2\ CO_3$	2.8589	grams
$Na\ Cl$	20.2621	grams
$Na\ NO_3$	13.5319	grams
$K_2\ SO_4$	2.0118	grams
$Mg\ SO_4$	1.7475	grams

The chemical reaction of these solutions was left unchanged. Agars of four different strengths were prepared from each solution by diluting the solution once, twice and three times with an equal volume of distilled water. The resulting agars, then, contained the

Table No. 7. Growth and Pigment Production on Synthetic Soil Agars.

Culture	Synthetic Agar lacking							
	Ca SO_4		$Na_2 SO_4$		$Na_2 CO_3$		Na Cl	
	Growth	Pigment	Growth	Pigment	Growth	Pigment	Growth	Pigment
No. 3.	moderate	brown	moderate	brown in spots	moderate	chocolate brown	moderate	brown
No. 8.	moderate	black	moderate	deep chocolate brown	moderate	black	moderate	chocolate brown
No. 93	moderate	chocolate brown	moderate	chocolate to black	moderate	chocolate to black.	moderate	chocolate brown
A. chroococcum.	moderate	dark brown to black	moderate	dark brown to chocolate	slight	none	slight	light brown

Culture	Synthetic Agar lacking							
	Na NO_3		$K_2 SO_4$		Mg SO_4		Mannite	
	Growth	Pigment	Growth	Pigment	Growth	Pigment	Growth	Pigment
No. 3	slight	none	moderate	chocolate brown	moderate	chocolate brown	very slight	none
No. 8	moderate	few dark brown specks	moderate	black	moderate	black	very slight	none
No. 93	moderate	few brown specks at bottom of streak	moderate	dark brown	moderate	black	very slight	none
A. chroococcum.	slight	none	moderate	dark brown	moderate	dark brown	very slight	none

PLATE I

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above solutions in the following amounts in which S represents the original strength: S, S÷2, S÷4, S÷8.

The agar was placed in test tubes, using about 7 c.c. per tube, and sterilized for 5 minutes in the autoclave at 120°C.

Streak cultures were next made on each agar of each strength, using cultures Nos. 3, 8, 93 and a stock culture of A. chroococcum. It will be remembered that No. 3 had retained its pigment producing power since isolation, No. 93 had lost it and No. 8 had shown little if any color beyond a dirty white. The results of these inoculations, when observed after fifteen days, are given in Table No. 7.

The best growth as well as pigment was secured on those agars represented by the formulae S÷4 and S÷8.

An inspection of the above table, No. 7, shows very clearly that the two limiting factors in the pigment production are sodium nitrate and mannite. The growth obtained on the agar lacking mannite was so very slight that it was, indeed, difficult to say whether there was any actual growth or whether it was just the line of the original transfer. This was not the case in the agar lacking sodium nitrate. The line of inoculation was well defined in all and in two there was a moderately heavy growth. There was absolutely no brown color but only a dirty white with culture No. 3 and the stock culture of A. chroococcum. In culture No. 8, there was a small amount of brown pigment at the bottom of the streak, and in the water of condensation, the remainder of the growth being dirty white; culture No. 93 contained a few brownish specks in the water of condensation, which under ordinary circumstances would have been overlooked; the streak proper was dirty white in color. Without exception, all the cultures produced abundant chocolate brown to black pigment on all the different agars except those lacking mannite and sodium nitrate. I feel that we are not begging the question when I make the statement that the reason we obtained no pigment in the absence of mannite was because we had no growth. To me, it was perfectly clear from the results of this series, that given a source of energy, the nitrate was the limiting factor in the formation of the dark brown color. I am not prepared to say, just now, whether the nitrate acts as a stimulant to growth, pure and simple, or whether it exercises an oxidizing function on certain bacterial products.

The results of this study were so striking and so self convincing that I have had two sets of the cultures reproduced in colors as nearly like the originals as possible. These were made from 20 day cultures by Miss Palmer, the Station artist. The upper set in Plate I, shows Culture 8, the lower, Culture 93. The numbers 1, 2, 3, etc. on the tubes indicate the composition of the agar as follows:

1. Lacking $Ca\ SO_4$
2. Lacking $Na_2\ CO_3$
3. Lacking $Na\ Cl$
4. Lacking $Na\ NO_3$
5. Lacking $Na_2\ SO_4$
6. Lacking $Mg\ SO_4$
7. Lacking $K_2\ SO_4$
8. Lacking Mannite.

By a system of elimination, we have shown above, that in the absence of nitrates there is practically no pigment formation. I was interested next in knowing just how necessary the other salts were to the production of the brown color, and whether the nitrates alone might not give the desired results. In order to determine this last point, a stock glucose agar was prepared as follows:

Stock Glucose Agar.

Tap water - - - - -	1000 c. c.
Glucose - - - - - -	20 grams
Agar-agar - - - - - -	20 grams

Glucose was substituted for mannite since two of my cultures produced pigment on the standard mannite agar, and it was determined experimentally that if this substitution was made in the stock agar, practically no color resulted with any of the cultures. By doing this all brown pigment producing factors were eliminated, and I had a medium which would support growth and to which the limiting compounds could be added.

A 10 per cent solution of $Na\ NO_3$ was prepared in distilled water and sufficient quantities of this were added to different lots of the stock glucose agar to give them a $Na\ NO_3$ content of 0.0, .01, .03, .05, .08, 0.1, 0.3 and 0.5 per cent respectively. In a 10 per cent solution of $Na\ NO_3$, 0.1 c. c. contains .01 grams of $Na\ NO_3$. In order to obtain the above percentages, the following amounts of this 10 per cent solution were added to respective 50 c. c. lots of liquified stock glucose agar: 0.0, .05 c. c., 0.15 c.c., 0.25 c.c., 0.4 c.c., 0.5 c.c., 1.5 c.c., and 2.5 c.c. The agar was placed in test tubes, sterilized for five minutes at 120°C. in the autoclave and slanted. Agar stroke inoculations were made on these with cultures Nos. 1, 3, 4, 8, 10, 93 and stock A. chroococcum

Our results with the series were gratifying beyond expectation. At the end of fourteen days, we had secured either an intense chocolate brown or a black pigment with every one of our cultures on those agars which contained the $Na\ NO_3$, but absolutely none on the control. The pigment varied in intensity with the amount of $Na\ NO_3$ present, the optimum quantity for the darkest pigment being between .05 and .08 per cent. In the early growth of the cultures a very nice gradation could be seen in the intensity of the colors, beginning with none in the control, a light brown in the .01 per cent, and a shade darker in each tube as the amount of $Na\ NO_3$ increased until the deep chocolate brown or black was reached at .05 and .08 per cent after which the shade of brown became somewhat lighter and remained almost constant. With age, this gradation of color was lost, all tubes except .01 and .03 per cent, showing an almost uniformly dark chocolate brown or black pigment. Plate II, prepared from twenty day cultures, illustrates culture No. 8 of this series. Beginning at the left hand side, the tubes contain 0.0, .01, .03, .05, .08, 0.1, 0.3 and 0.5 per cent of

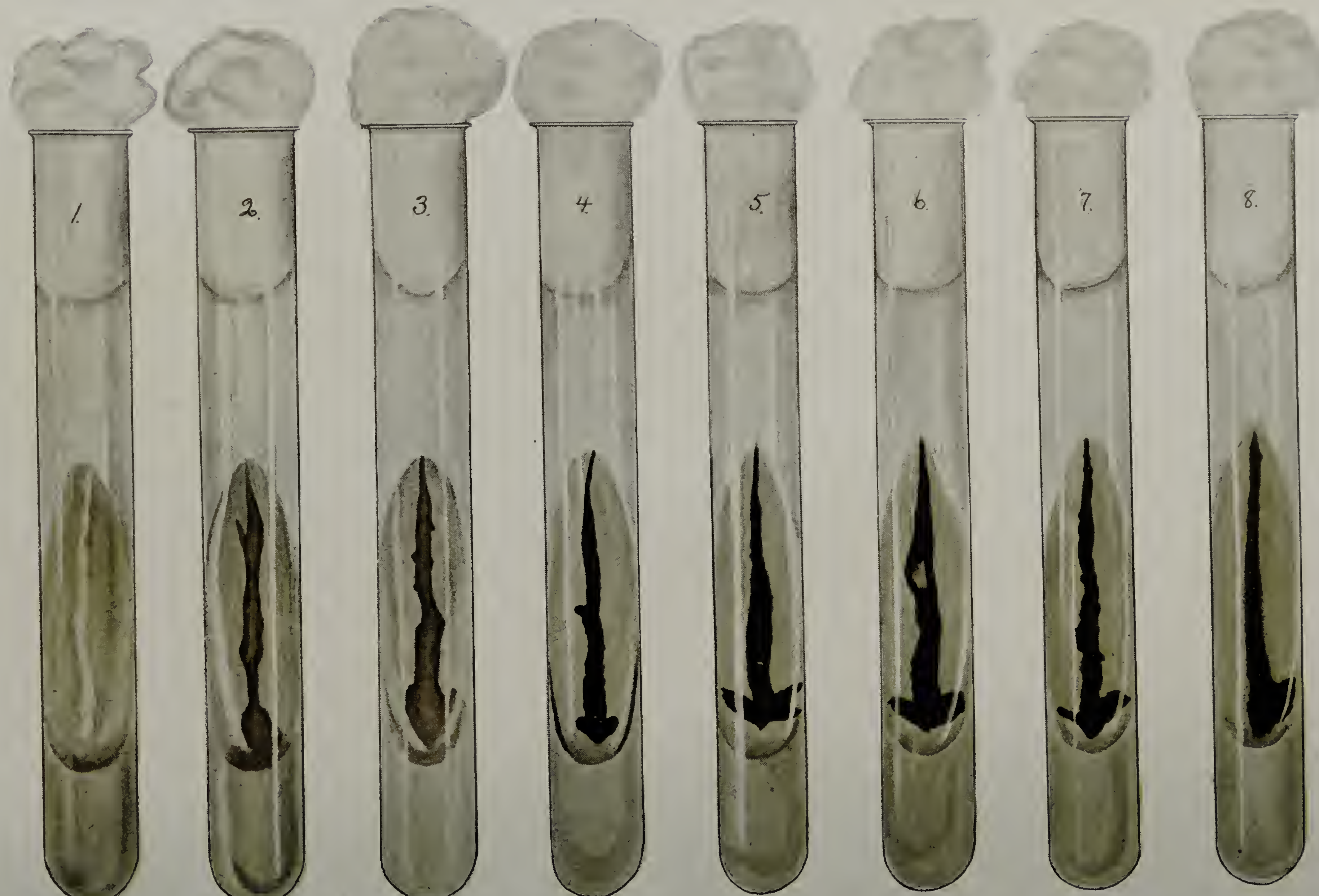

PLATE II

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$Na\ NO_3$ respectively. After one has seen this experiment there can be no questioning the fact, that given a supply of carbon, $Na\ NO_3$, of and by itself, can cause A. chroococcum to produce a chocolate brown to black pigment.

This observation is substantiated by the work of Beijerinck[1] in which he has shown that "Pigment formation could also be observed in pure cultures if the mannite was replaced by dextrose and *nitrate* in minimum quantities was added." In the application of these results to field conditions, we have a very tenable explanation of the brown color of the soil. It has been shown that these soils are abundantly stocked with Azotobacter chroococcum, and in the presence of the large amount of nitrates which they carry, the inevitable consequence must be the production of an intensely brown pigment, which has brought the brown spots to our attention.

In 1904 Heinze[2] expressed the view that possibly the dark color of soil was due in a degree to the pigment of A. chroococcum. Lohnis[3] was not inclined to accept this statement, but Omeliansky and Ssewerowa[4] are of the opinion that while it would be a mistake to attribute the dark color of soils to this cause altogether, one has no right to deny the possibility of its occurrence. They have shown experimentally that a brown pigment is produced by Azotobacter in a medium containing chalk and hydrolized starch, both of which are present in soils as $Ca\ CO_3$ and as decomposed plant tissue respectively. Therefore, they concluded that, "The part which Azotobacter plays in the dark color of the soil is not to be overlooked."

The intensely brown pigment which all of our cultures have shown in this and the preceding series seems to identify them all as varieties of A. chroococcum, and consequently they may be considered as such in this bulletin. The variation which has been noted before is in perfect harmony with the observations of Omeliansky and Ssewerowa[5] who state that, "Between the colored and colorless, intermediate forms exist in which the pigment formation is more or less limited."

THE RELATION OF NITROGEN COMPOUNDS OTHER THAN NITRATES TO THE PRODUCTION OF BROWN PIGMENT.

Now if nitrates by themselves can bring about pigment production, may not the same be equally true of other forms of nitrogen? To answer this question, a number of different agars were prepared, each containing a different form of nitrogen. The list included nitrogen as peptone, asparagin, ammonium chloride, ammonium sulphate and

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1. Cent. f. Bakt. Abt. II, Bd. 7, p. 561. 1901.
2. Cent. f. Bakt., Abt. II., Bd. 12, p. 357; Bd. 16, p. 341. 1906
3. Lohnis, Handb. d. Landw. Bakt. p. 712.
4. Cent. f. Bakt., Abt. II., Bd. 29 p. p. 649, 650. 1911.
5. Cent. f. Bakt., Abt. 11., Bd. 29, p. 643. 1911.

sodium nitrite. With the exception of the peptone, a solution of each was prepared containing the nitrogen equivalent of a ten per cent. solution of $Na\,NO_3$. This was done so that the various agars would be comparable to the sodium nitrate series in point of nitrogen content. The percentage equivalents for the salts mentioned, corresponding to a 10 per cent solution of $Na\,NO_3$ are as follows:

Asparagin - - - -	8.8231 per cent
$NH_4\,Cl$ - - - - - -	6.2887 per cent
$(NH_4)_2SO_4$ - - -	6.5894 per cent
$Na\,NO_2$ - - -	8.1189 per cent

The proteid (peptone) agar was made by adding to the stock glucose agar, standard nutrient broth, neutral in reaction, in the following proportions: 0.0, .1, .2, .5, .8, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, and 10.0 per cent. The other agars were prepared by adding to respective lots of stock glucose agar the above solutions in amounts corresponding to 0.0, .01, .03, .05, .08, 0.1, 0.3 and 0.5 per cent of $Na\,NO_3$. For every 50 c. c. of the stock glucose agar the following quantities of these solutions were required to give the above percentages: 0.0 c. c., .05 c. c., .15 c. c., .25 c. c., .4 c. c., .5 c. c., 1.5 c. c. and 2.5 c. c. respectively. The six different agars were placed in test tubes using about 7 c. c. each, sterilized in the autoclave for five minutes at 120°C. and slanted. Stroke cultures were made on these employing cultures Nos. 3, 8, 93 and our stock culture of A. chroococcum.

At the end of eighteen days, there was no brown pigment produced by any of the cultures on the proteid nitrogen agar containing beef broth, although there was luxuriant growth in all of the tubes. No pigment whatever, was made by any of the cultures on either the amido nitrogen agar, containing asparagin, or the ammonia nitrogen agars, containing respectively $NH_4\,Cl$ and $(NH_4)_2\,SO_4$. The growth ranged from slight to moderate. On the nitrite nitrogen agar, with cultures Nos. 8 and 93, we obtained a decided chocolate brown in the tubes which contained the $NaNO_2$ corresponding to .01 per cent $NaNO_3$. All of the inoculations with these two organisms grew, but without color. Culture No. 3 gave a brown and chocolate brown pigment with $NaNO_2$ corresponding to .01 and .03 per cent $Na\,NO_3$ respectively. The stock culture of A. chroococcum grew very feebly on this agar as on the others, and produced no pigment. Control cultures on the stock glucose agar, to which no nitrogen was added, were carried along with the above. Growth took place but there was no evidence of any pigmentation.

The results of this work indicate that in the presence of nitrates, A. chroococcum produces an intensely brown to black pigment; that nitrites in certain proportions, exercise this influence to a less degree; and that nitrogen as $NH_4\,Cl$, $(NH_4)_2SO_4$, asparagin, and peptone has no effect upon this function.

Solubility of the Pigment.

In their extended studies on the formation of pigment by A. chroococcum, Beijerinck[1], Omeliansky and Ssewerowa[2] have found that the pigment is insoluble in the ordinary solvents. On this point, Beijerinck says, "Insoluble in water, alcohol, ether, chloroform, carbon disulphide, the pigment went into solution under the influence of alkalies, whereby it probably underwent a chemical change." Omeliansky and Ssewerowa state that, "The pigment is insoluble in the usual solvents. Only under the action of alkalies does it go into solution, thereby, nevertheless, changing itself chemically."

The relation of alkalies to the solution of pigment, as described by these investigators, suggests a further explanation for the brown stain which we find on the ditch banks and irrigation furrows. May it not be possible that under the influence of the soil nitrates, Azotobacter chroococcum produces an intense pigment which is brought into solution by the alkaline soil waters, and once in solution, the coloring matter is carried to the surface where it becomes concentrated and produces the characteristic appearance? While we have given but little consideration to this explanation of the color, we have reasons for believing that there is more to this hypothesis than mere speculation and idle fancy.

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SUMMARY.

The power to fix atmospheric nitrogen is a property common to many cultivated Colorado soils.

This power is not confined to nitrogen fixation in solutions, but is manifested in soils as well.

"The rate of fixation of nitrogen obtained is sufficient to account for the nitrates found in the soil provided that it is nitrified. The rate of nitrification obtained is sufficient to account for the formation of the nitrates found, in most cases if not all of them."[3]

The nitrogen fixing power is not limited to any geographical locality or class of soils, however, the adobe shale soils, both in a raw

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[1]Loc. cit., page 39.
[2]Loc. cit., page 39.
[3]Bulletin 178, p. 96, Colo. Exp. Station, 1911.

state and newly cultivated, possess little, if any, nitrogen fixing power.

Excessive nitrates either destroy or greatly attenuate the nitrogen fixing flora of a soil.

A limited amount of soil nitrate does not seriously affect the nitrogen fixing power of a soil.

Azotobacter chroococcum appears to be the dominant nitrogen fixing organism in the soils studied.

The dark brown color of the nitre soils is due, in a large part, to the pigment produced by Azotobacter chroococcum.

Given a source of energy, the nitrate is the limiting factor in the production of the brown color.

In the presence of nitrates, Azotobacter chroococcum develops a chocolate brown to black pigment; nitrites, in certain amounts, produce similar results, but to a less degree; nitrogen as NH_4Cl, $(NH_4)_2SO_4$, asparagin, and peptone has no effect upon this function.

The highly colored extracts obtained from certain nitre soils suggest that the pigment of Azotobacter chroococcum may be soluble in the alkaline soil waters.

Excessive soil moisture, by interfering with the growth of Azotobacter chroococcum, prevents the formation of the brown color on the soil, and makes the fixation of atmospheric nitrogen impossible.